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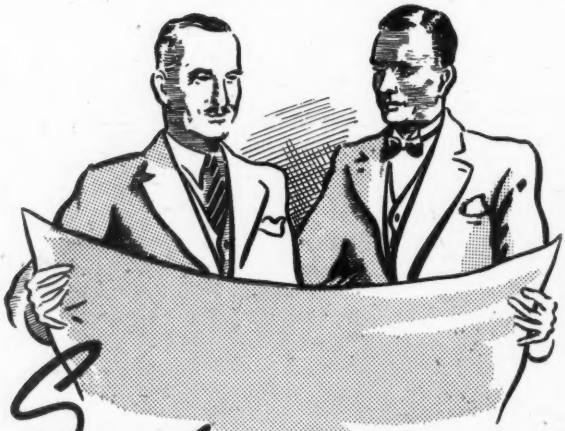

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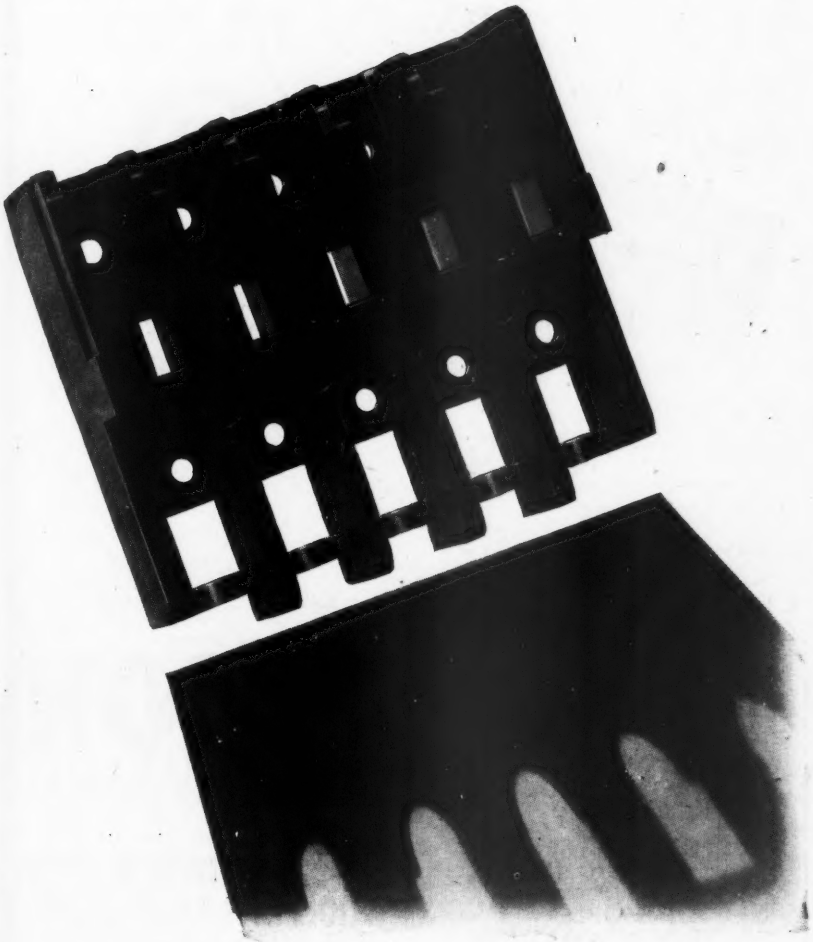

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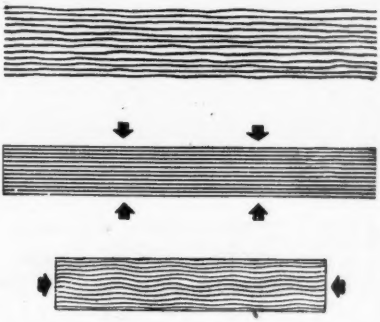
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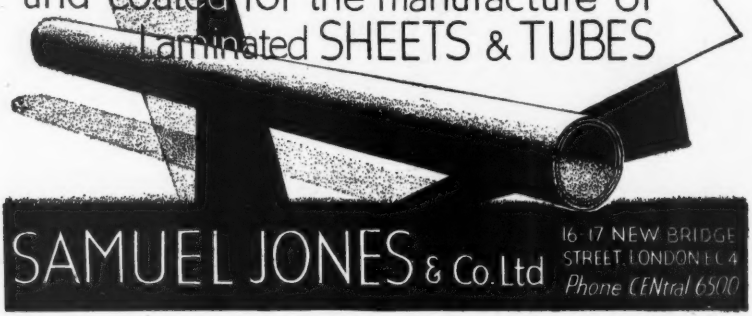

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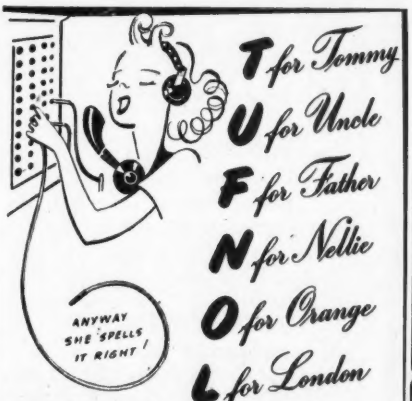

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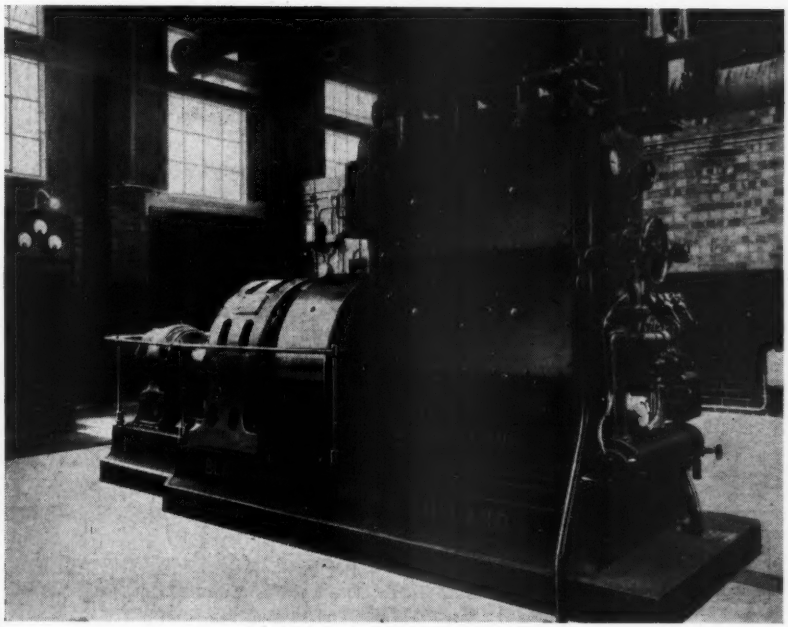

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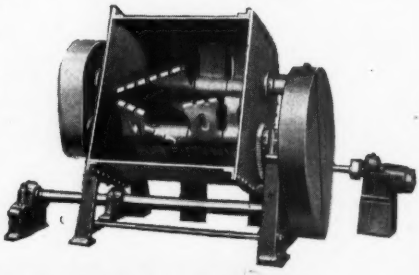

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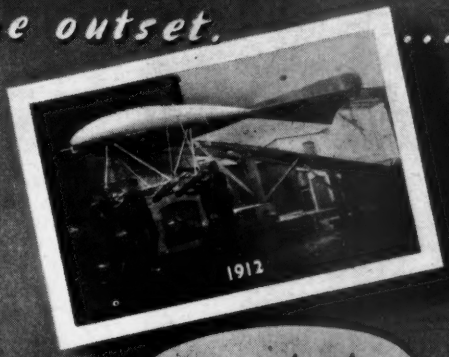

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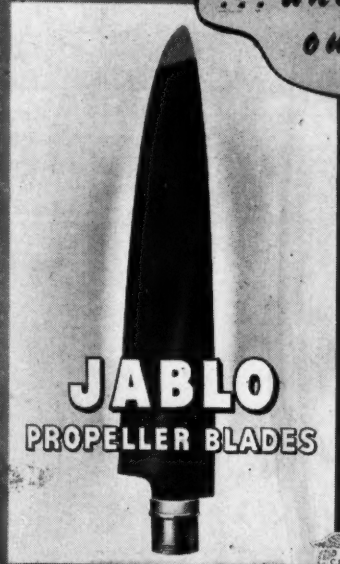

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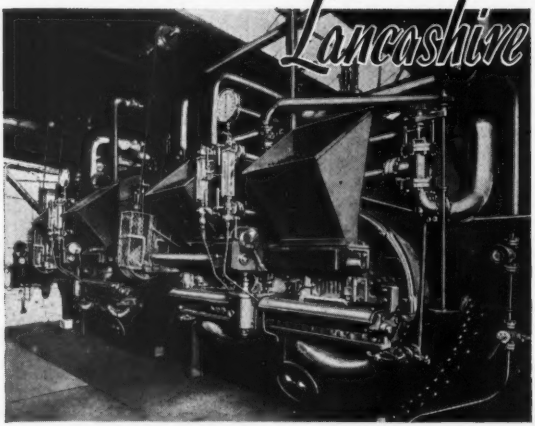

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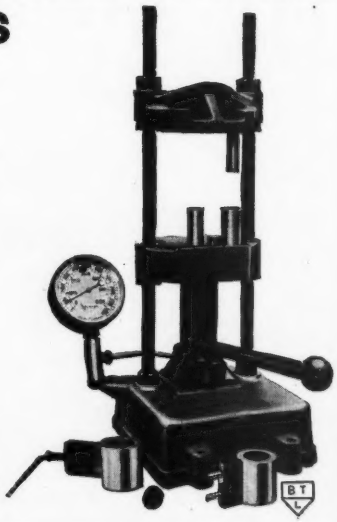

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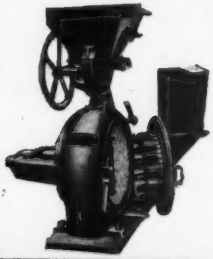

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Pioneers in the Plastics World

Vol. VII. No. 74 JULY, 1943

Plastics

Dealing with the Manufacture, Uses and Potentialities of Plastic Materials

Proprietors - - TEMPLE PRESS LIMITED
Managing Director - ROLAND E. DANGERFIELD

Editor - M. D. CURWEN, B.Sc., A.I.C.
Offices - Bowling Green Lane, London, E.C.1

CONTENTS

	Page		Page
Editorials	278	Inquiries and Answers ..	302
Metallizing Plastics, by E. E. Halls	281	Sealing Porous Castings ..	303
Working of Polyvinyl Chloride and Polyisobutylene	287	Production News	306
World's Industry Uses Plastics	292	Co-operation between User and Moulder, by W. M. Halliday	308
Plastics in Aircraft Construction, by D. Warburton Brown	296	Resinoids and Other Plastics as Film Formers, by B. J. Brajnikoff	314

NOTICES

All instructions, matter and passed proofs for all kinds of advertisements must reach the Head Office of "PLASTICS" by the 24th of each month to ensure insertion in the following month's issue.

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The fact that goods made of raw materials in short supply because of war conditions are advertised in this journal should not be taken as an indication that they are necessarily available for export.

EDITORIALS

Plastics from the Farm

IN the United States, where the problem of synthetic rubber manufacture has loomed so large, the question as to whether the farmer, who can provide the grain or the molasses to make the alcohol to produce the synthetic rubber, should be given a chance against the petroleum producers, threatens to become a major political theme. Whether this is a political racket or not, one thing is certain: the farmer has produced much of value for the plastics industry and can do more, whether it is in the production of natural plastics such as rubber, or the half-way materials such as cotton, flax, jute, soya bean, sugar, starches, milk, etc., which by chemical treatment can be converted directly to plastics, or to chemical compounds from which plastics may be built synthetically.

The whole problem has been ably discussed on both sides of the Atlantic by two well-known individuals in the plastics industry. In America our old friend E. F. Lougee, one time Editor of "Modern Plastics" and now chairman of the Advisory Board of the Plastics Industries Technical Institute, California, has written a pleasant little book entitled "Plastics—from Farm and Forest," which has just been published by the Institute. It makes no pretensions at being chemical, and gives no engineering data, since it has been done for those who know little about plastics. It loses nothing because of this exclusion, therefore, and builds up a convincing story of the "magic" of plastics for his readers. Glamorizing of plastics is, of course, quite common in this country, and we ourselves have objected to it when we are in a piously scientific and cold frame of mind, but after all even the scientist sees in, say, Carother's papers on polymerization, or the production of magnesium metal from sea water, something magical, if he temporarily forgets the heartaches, headaches and very mundane troubles that have always accompanied such work before it reaches fruition.

However, Mr. Lougee deals with a vast range of agricultural materials that the U.S.A. farmers or foresters can produce, from dandelions and grain for producing rubber to soya bean for producing protein plastics, skim milk, ramie, hulls and cobs, walnut shells, lignin and farm wastes.

There is only one little point we should reproach him on. He states, and most people in this country seem to think the same, that John Wesley Hyatt, of Albany, New York, "discovered the first synthetic plastic" (meaning cellulose nitrate) "in 1869 . . . and gave the world a brand-new material it never had seen before."

While no doubt John Hyatt invented the name "Celluloid" and improved on the manufacture, yet it seems to be true that Daniel Spill, working in the town of London, Eng., cast and moulded nitrocellulose before 1869 and sold an excellent imitation of ivory under the name of "Xylonite." No doubt B.X. (Plastics), Ltd., could confirm this.

Of the production of synthetic rubber from grain, via alcohol, Mr. Lougee quotes Dr. W. J. Hale, former organic chemistry professor at the University of Michigan, and now consultant to Dow Chemical Company, as saying he could produce all the rubber the nation needs in a year if given money, men and priorities, at 15 cents a pound, from grain.

Dr. H. Barron, in his lecture on the same subject at Southampton recently, also stressed the importance of agricultural products for plastics manufacture. We presume that Dr. Barron was striving

to put across his ideas for Great Britain. Here, where conditions are extremely different from those which obtain in the U.S.A., it is most difficult to imagine that like opportunities will occur for our farmers, even though our farming has increased many fold during war-time. Even though the prices of petroleum and industrial alcohol are fairly equal yet we think most people forget that petroleum is an industry which gives its workers the highest wages and salaries in the world, while agriculture gives its workers the lowest. Improve the conditions of the farm workers and the price of industrial alcohol made from indigenous grain must go up, throwing the balance still more against it.

Where Lougee and Barron and the whole scientific world see alike is in the real wastes in agriculture and forestry and wood working. Straw, hulls, shells, sawdust—true and often dangerous wastes—should prove valuable materials if only collection and transport costs could be cut down to reasonable dimensions.

The Old Man Shows His Medal

A BIG landowner in one of our great hunting and farming shires has written us about plastics, which goes to show how plastic-minded the nation is now. He has the commendable habit of distributing annually to certain of his tenants and other farm workers as a mark of his appreciation for their work, medallions made from precious metals. In view of their rareness and the difficulty of their fabrication in war-time, he asks whether or no we can recommend their production in plastics.

Frankly, we are in a dilemma. Here is a case where cost is not one of the factors at all. In fact, the price of the die for a few special medals per annum would be comparatively high. The trouble lies in other factors.

In the past we have been enthusiastic and successful in recommending plastic medals to be worn by the members of the Accrington Branch of the Brotherhood of Road Paviors and Asphalt Melters at their annual dinners. We agreed heartily in the passing of the special resolution to issue plastic tokens by the Brighton and Hove Council for their British Restaurants. We have also presumed, because of the huge tonnage presented by Hitler, that all Iron Crosses were made of plastics, and in view of their ultimate destination that they were made of non-inflammable polyvinyl chloride.

But here the case is surely somewhat different. While the plastic medal may be æsthetically more beautiful than the stupidly yellow gold type, and while the recipient may have the tremendous advantage of being able to rub out pencil marks if his plastic medal is resilient enough, yet were we given the choice we must admit we would hesitate. We are, of course, in a special category, with our venal minds, and it would be comforting in our old age to be able to say: " I could raise a fiver on this." As Sid Walker might say: " Which would you choose, chums? "

On the other hand, the farmer is different. Shades of John Masefield! What could not be made of it:—

Devonshire Split

Enter Uncle T. Cobleigh with Cornish pastie in one hand and plastic medal in the other.

Uncle T.C.: Look, Nan, the old squire 'as give oi thiccy medal. 'Oi been plowin' the mowey field for nigh on forty year, that's wot it's fer. Look, Nan, 'ow beeoutiful 'tis. Like yer eyes 'tis. All blue and green wi' yellow spots, and made o' plastics.

Nan (reminiscently): The sky was blue an' my little frock was green wi' yellow spots when you came coortin' me. 'Tis luvely—like a jewel in Dartymoor grass. An' all made of pastie, tew!

Uncle T.C.: Plastic, I sed, yer old fule, not pastie. (Hits her on head with axe. Gazes at medal.) Yew beeouty! Praabably got a power factor of 0.0001, tew.

GOOSE AND GANDER

Sir Herbert Morgan, at the annual general meeting of Smith's Potato Crisps (1929), Ltd., pointed out that the shortage of certain popular commodities had encouraged a great deal of substitution.

"But," he went on, "the public have found that substitutes are never 'just as good' as advertised branded products, or anything sold under a name of established reputation."

We must point out that the public has found nothing of the sort, and Sir Herbert Morgan, who is also intimately connected with the plastics industry, should know better than to use the word so carelessly.

A substitute may be worse than, as good as, or better than the object it replaces. The Oxford English Dictionary says nothing about "quality" in giving the meaning of this word, and until a new definition of the word meaning inferiority is made, which Heaven forbid, the dictionary meaning should stand. Sir Herbert knows full well that plastics very frequently are superior substitutes for older materials and will continue to substitute until such time as better materials replace it in turn.

In this life, you cannot eat your spud and still have it.

LAC RESEARCH IN INDIA

The annual report of the Indian Lac Cess Committee contains interesting data regarding the research work carried out by the Indian Lac Research Institute.

In the chemical section during the year under report it was found possible to substitute, partially or fully, some of the imported chemicals hitherto required for the preparation of shellac-formaldehyde-urea moulding powders by others which are more easily available or could be prepared in this country starting from indigenous raw materials. For example, a large part of the urea could be replaced by a smaller percentage of aluminium chloride, or it could be totally replaced by a smaller percentage of thiourea, the preparation of which, from the waste gas-liquor of industrial gasworks, has been made possible through the investigations carried out in the laboratory. There have been a considerable number of inquiries for laminated boards and, apart from giving advice and training to several interested inquirers, considerable progress has been made in working out improvements in the details of the process. A new line of investigation that has been taken up during the year and has yielded promising results is the preparation of compositions for the cold-moulding process to be followed by prolonged heat-curing.

Several varnishes for the manufacture of emery paper and for efficient waterproofing of moulded articles have been prepared. By modifying shellac with dibasic acids and oxidizing agents, strong adhesive compositions have been prepared.

Considerable progress has been made in evolving new types of shellac-rubber combinations with useful properties, especially with asbestos, cement and oxidized coal-tar fractions.

Laminated gramophone records of satisfactory performance have been prepared with a core of laminated paper disc and a modified shellac composition.

The preparation of urea from cyanamide on a semi-large scale has been worked out in all its details.

Several resin powder-moulding firms in India have been helped by personal visits of assistants of the Institute and experimentation in their own factories to enable them to manufacture on a commercial scale moulded goods required for a variety of urgent war needs, for example, neck-rings, components for telegraphic and telephone equipment, general electrical goods, etc. *Ad hoc* investigations have been undertaken as a result of inquiries, and in most cases satisfactory solutions have been offered after the necessary investigations in the laboratory.

New Heating of Plastics

It has long been realized that for many purposes the provision of heat for drying by, say, heated air would be replaced by the application of direct rays, for example, infra-red rays.

The paint industry was the first to be affected by the new method, since it is one in which it is most applicable, that is the drying of surface films by evaporation of solvent and oxidation or polymerization of the original liquid base. The process is now being carried out in this country and the U.S.A. for the treatment of automobile finishes and other surface films employed in a wide range of industries.

A more recent application of infra-red rays is that in the building-up of structures from resin-bonded plywood, where the production of heat by electricity or steam is not suitable because of the type of clamp holding the laminated structure.

Metallizing Plastics
(continued)

A Complete Survey and Critical Study of the Modern Methods of Metal Film Formation on Plastics for their Protection and Decoration

by E. E. HALLS

2. Electrically Conducting Films Applied by Means of Metal Powder in Varnish or Lacquer Medium

It has, in general, been stated that metal powder finishes consisting of aluminium, brass, bronze or copper powders applied in an organic medium such as an air-drying oil varnish, a stoving oil or synthetic varnish or a cellulose lacquer do not provide films having properties of electrical conductance. In the first place, these metal powders almost invariably have an oxide film completely over the surface of each particle, and this film renders the particle relatively insulating. Additionally, the incorporation of the powders into liquid binding media automatically entails that each particle becomes coated with the binder, which, in turn, adds insulating properties depending upon the thickness of the coating so applied and upon whether the particles break the film and so contact with one another in a continuous manner. To produce conducting metal powder varnishes or lacquers it is therefore necessary to overcome these two adverse features. That they can be overcome to a more or less degree, at least for some purposes, is evidenced by the fact that the materials have been extensively used, particularly for conducting coatings on glass bulbs or radio valves and for screening electro-magnetic apparatus or on moulded or laminated phenolic resin containers. Further, several patents refer to finishes in this category.

The question of the insulating properties of the binding medium is solved by reducing the quantity of binder to the bare minimum required to give adhesion in the particular circumstances. This quantity is naturally dependent upon the nature of the material to which applied and upon whether the surface of the material can also be roughened as by sandblasting to provide a key. Again, the solvent vehicle can often be modified or chosen to suit the base material, in order to improve adhesion, e.g., acetone for cellulose acetate or nitro-cellulose.

The problem of the oxide film can be tackled by removing it by chemical dissolution or by reduction. Nevertheless, it does not follow that success will be met in all cases. For example, in the case of brass, bronze and copper powders, the oxide can successfully be removed by dissolving it in sulphuric acid in acetone solution, washing and drying. Again, it can very successfully be removed by reduction in a current of coal gas and cooling off in coal gas. It can be removed, but not with the same degree of consistent success, by reducing in a current of hydrogen and cooling off in hydrogen. Copper and copper-rich alloys are the only ones with which commercial success has been achieved, as evidenced by exploitation of these processes in industry. In the case of aluminium, whatever processes have been tried have been failures because the aluminium powder re-oxidizes so rapidly that it is back to its original condition before it can be incorporated with the binding medium.

Some notes covering investigations in this field are of interest. All the brass, copper and aluminium powders employed were the normal products supplied for

paint finishes and having the particles in flat plate form. Nickel was also examined in the only form available, this being a powder of approximately 200 mesh. It did not respond satisfactorily to reduction treatments either in hydrogen or coal gas, and the resistance values obtained were high, but this may have been due to the fact that the powder was not of suitable form for incorporating in the bronzing medium. It was dense and did not suspend properly, so that in the applied film the particles were individually positioned rather than aiding the formation of a homogeneous film.

Results of Investigations

Detailed results using different mixtures are summarized in Table 7, which is self-explanatory. It was concluded that satisfactory conducting finishes could be obtained by means of metal powders suitably treated. The preferred treatment is reduction by means of coal gas, and the best powder to use is a copper powder of relatively fine particle size. The bronzing medium can be applied by automatic spray, in order to control the film thickness deposited, but if sprayed by hand two coats are advisable in order to compensate for the variation in thickness of coating that is inevitable when applied by hand. Such coatings have been employed upon glass radio valves which operate warm and stand up satisfactorily for long service periods without increase in resistance and certainly without loss in adhesion. On the other hand, if excessive heat is to be withstood, tests should be made beforehand covering this factor, to ensure that undue oxidation does not occur, with consequent loss of conductance.

It will be seen that the results given in Table 7 cover a number of metal powders of different composition and differing degrees of coarseness. It refers to several methods of pretreatment, and to a range of concentrations with respect to binding media and diluents. The metal powders (nickel excepted) are those already characterized in Table 4. The binding medium was the cellulose base material, sample No. 2 of Table 2. The diluent was a high-class thinner for cellulose lacquers or enamels having an approximate composition of 45 to 50 per cent. amyl acetate and 50 to 55 per cent. benzine. Acetone was also used with equal success. The composition sprayed is detailed in the table, being reduced in all cases to a metal powder basis of 10 grams to render comparison easier. All the tests were made on glass, which had not been roughened or prepared in any way.

Samples Nos. 1 to 4 inclusive cover aluminium and nickel, comments upon which have already been given. Samples Nos. 5 and 19 show that for brass and copper, despite pretreatment of the metal powder, the normal lacquering composition is excessive with respect to binder for conductive films to be obtained. Conductivities of 1 sq. ohm or less are of good order; values of 4 or over have been regarded as poor, although quite good for many purposes. The brass samples Nos. 6 to 13 inclusive do not show the low conductivity values desired.

Specimen No. 14 with medium copper powder pretreated in sulphuric acid in acetone is noteworthy, satisfactory for adhesion and conductivity.

Specimens 15 to 18, coarse copper reduced in hydrogen, demonstrate the variable conductivity values yielded by this method of pretreatment. They contrast with the remaining results using copper powders reduced in coal gas. Sample No. 23 shows that the finish withstands limited heat, but not indefinite periods at elevated temperatures without increase in resistance. Sample No. 25 shows that the reduced copper powder cannot be kept indefinitely without resistance of the ultimate coating suffering, due to increase in resistance of the copper powder, presumably due to surface oxidation. Samples Nos. 35 and 36 show the influence, not very seriously adverse, of allowing the spray mixture to stand for 24 hours before application, while No. 37 shows the ill-effects of allowing it to stand for 48 hours. Samples Nos. 38, 43 and 45 show the tendency for increase in resist-

ance by storing the reduced copper powder for one and two days before mixing and using, although the values are still very good.

Preparation of Powders

It is again stressed that in all the above tests the basis material was glass, used without any roughening treatment. Two qualities are all-important, adhesion and conductivity, and the retention of these during service. Results on plastics are at least equal to those on glass. The phenolic and amino resin plastics are the most likely to be concerned in practice, and these in the form of sheets, boards, tubes or mouldings. Adhesion is of similar order to that secured on glass, and it can be further improved by a preliminary abrasive blasting with sand or shot. A serviceable lacquer composition comprises 10 gms. of fine copper powder (reduced in coal gas), 10 ml. of bronzing medium and 15 ml. of acetone or diluent. With the light roughening, the proportion of medium can be reduced if higher conductivity values are required.

It is evident that two pretreatments of the copper and brass powders are practicable, a wet and a dry process, and each has its practical merits and demerits. The wet process is very simple from the plant and operation point of view, but it does involve the handling of acid and the thorough washing of the metal powder to remove all traces of acid. The operations entailed in this are as under:—

(a) The copper or brass powder is first rinsed with acetone to remove any traces of oil or grease that would otherwise make wetting of the powder with dilute acid rather difficult. Quite a rapid rinse is sufficient, and it is not necessary to remove residual acetone or to dry off. The acetone can be removed by decantation, centrifuge or filtration.

(b) The metal powder is deoxidized by washing with dilute sulphuric acid of strength 10 to 20 per cent. by weight. Contact for about half a minute is sufficient. Acid is filtered off and can be used for treating further lots of powder. The metal powder is rapidly washed on the filter with cold water to remove acid completely. After the final water wash the powder is rinsed through with acetone as soon as the water has drained through.

(c) The metal powder, still wet with acetone, is mixed in with the medium and thinners ready for use. This avoids any possibility of reoxidizing before use, a difficulty that exists if the powder is allowed to dry off.

The dry process involves reduction in coal gas. This is better than using hydrogen, because the latter entails a higher temperature and inevitable trouble from caking. Coal gas enables a temperature of 300 to 350 degrees C. to be used because of its carbon monoxide constituent, this being a more efficient reducing agent than hydrogen at the lower temperatures. The process is completed in one operation. No preliminary degreasing is required. The powder is loosely packed in a glass tube, coal gas passed through to expel air, and then the temperature raised to 300 degrees C. Reduction is rapid and can be visually followed by the colour change. The charge is then cooled off with the gas stream still gently flowing. It is then ready for mixing with the medium.

It will be seen that both processes are simple and effective, and it is only a question of choosing one of them to suit local conditions. The capacity of the plant should be such that can comfortably handle daily requirements. The product should be used within 24 hours—that is, the same or the next day.

Developments in the electrical industries prior to the war were towards the adoption of aluminium or light alloy panels for equipments. These were chosen on their merits, chiefly for lightness of weight, cleanliness, corrosion resistance and ease of finishing. With the forced restrictions in the use of aluminium, a substitute material has had to be found. Plastics are the only ones that give the same advantages as the aluminium alloys. Phenolic laminated board with an amino resin veneer of appropriate shade on the face side satisfies weight and finish, but if electrical shielding is required, one face

Table 7.—Metal Powder Lacquer Sprayed Films for Electrically Conducting Coatings—Summary of Test Results.

Sample No.	Metal powder	Pre-treatment of metal powder	Spray metal, grams.	Lacquer medium, ml.	Composition diluent, ml.	Number of coats	Thickness of film	Adhesion	Resistance (square ohms)	Remarks
1	Aluminium	Reduction in coal gas ..	10	5	25	Two	Thick	Good	Infinity	Unsatisfactory for conductivity.
2	Aluminium	Reduction in hydrogen ..	10	5	25	Two	Thick	Good	Infinity	Unsatisfactory for conductivity.
3	Nickel	Reduction in hydrogen ..	10	2.5	10	One	Medium	Poor	5,000	Unsatisfactory for conductivity.
4	Nickel	Reduction in coal gas ..	10	2.5	10	One	Medium	Poor	5,000	Unsatisfactory for conductivity.
5	Brass, fine	Reduction in hydrogen ..	10	100	50	Two	Thick	Good	Infinity	Normal lacquer composition for bronze finishes.
6	Brass, fine	Reduction in hydrogen ..	10	20	20	Two	Medium	Good	20	Poor for conductivity.
7	Brass, fine	Reduction in hydrogen ..	10	5	5	One	Medium	Good	8	After buffing on soft mop, resistance 1 ohm.
8	Brass, fine	Reduction in hydrogen ..	10	5	5	Two	Thick	Good	6	Poor for conductivity.
9	Brass, fine	Reduction in hydrogen ..	10	2.5	10	One	Thin	Poor	30	Poor for conductivity.
10	Brass, fine	Reduction in hydrogen ..	10	2.5	10	Two	Thick	Poor	8	Poor for conductivity.
11	Brass, fine	Reduction in coal gas ..	10	5	12.5	One	Thin	Fair	40	Poor for conductivity.
12	Brass, fine	Reduction in coal gas ..	10	5	12.5	Two	Thick	Fair	4	Poor for conductivity.
13	Brass, coarse	Reduction in coal gas ..	10	5	12.5	Two	Medium	Good	40	Poor for conductivity.
14	Copper, medium	Sulphuric acid in acetone	10	1	10	Two	Medium	Good	0.8	Satisfactory for adhesion and conductivity.
15	Copper, coarse	Reduction in hydrogen ..	10	20	20	Two	Medium	Good	4	Conductivity too variable.
16	Copper, coarse	Reduction in hydrogen ..	10	10	12.5	One	Thin	Good	20	
17	Copper, coarse	Reduction in hydrogen ..	10	10	12.5	One	Thin	Good	250	
18	Copper, coarse	Reduction in hydrogen ..	10	10	12.5	Two	Thick	Good	28	
19	Copper, coarse	Reduction in coal gas ..	10	100	50	Two	Medium	Good	Infinity	Normal lacquer composition for bronze finishes.
20	Copper, coarse	Reduction in coal gas ..	10	20	20	One	Very thin	Good	30	Satisfactory for adhesion and in thick coats for conductivity.
21	Copper, coarse	Reduction in coal gas ..	10	20	20	One	Thin	Good	4	
22	Copper, coarse	Reduction in coal gas ..	10	20	20	Two	Thick	Good	0.8	
23	Copper, coarse	Reduction in coal gas ..	10	5	12.5	Two	Medium	Fair	0.8	Resistance unchanged after heat test of 1 hour at 135°C., but became infinity in 100 hours.
24	Copper, coarse	Reduction in coal gas ..	10	5	12.5	One	Thick	Fair	1.0	Satisfactory for conductivity.

Table 7 (contd.)

Table 7 (contd.)

Sample No.	Metal powder	Pre-treatment of metal powder	Spray metal, grams.	Lacquer medium, ml.	Composition diluent, ml.	Number of coats	Thickness of film	Adhesion	Resistance (square ohms)	Remarks
25	Copper, course	Reduction in coal gas ..	10	5	12.5	Two	Medium	Fair	6,000	The reduced copper powder kept for one week in stoppered bottle before use.
26	Copper, fine	Reduction in coal gas ..	10	5	12.5	One	Very thin	Fair	3.0	Conductivity satisfactory, but adhesion could be improved.
27	Copper, fine	Reduction in coal gas ..	10	5	12.5	One	Very thin	Fair	3.5	
28	Copper, fine	Reduction in coal gas ..	10	5	12.5	One	Thin	Fair	1.4	
29	Copper, fine	Reduction in coal gas ..	10	5	12.5	One	Thin	Fair	1.8	
30	Copper, fine	Reduction in coal gas ..	10	5	12.5	One	Thin	Fair	1.4	
31	Copper, fine	Reduction in coal gas ..	10	5	12.5	One	Thin	Fair	1.7	
32	Copper, fine	Reduction in coal gas ..	10	5	12.5	Two	Medium	Fair	0.8	
33	Copper, fine	Reduction in coal gas ..	10	5	12.5	Two	Thick	Fair	0.5	
34	Copper, fine	Reduction in coal gas ..	10	5	12.5	Two	Thick	Fair	0.7	
35	Copper, fine	Reduction in coal gas ..	10	5	12.5	Two	Medium	Fair	1.6	Lacquer mixture allowed to stand one day before use.
36	Copper, fine	Reduction in coal gas ..	10	5	12.5	Two	Medium	Fair	1.4	Lacquer mixture allowed to stand one day before use.
37	Copper, fine	Reduction in coal gas ..	10	5	12.5	Two	Medium	Fair	10,000	Lacquer mixture allowed to stand two days before use.
38	Copper, fine	Reduction in coal gas ..	10	5	12.5	Two	Medium	Fair	0.8	Reduced copper powder stored in stoppered bottle one day before mixing.
39	Copper, fine	Reduction in coal gas ..	10	5	12.5	Two	Medium	Fair	0.6	Reduced copper powder stored in stoppered bottle one day before mixing.
40	Copper, fine	Reduction in coal gas ..	10	20	20	Two	Medium	Good	1.5	Satisfactory for adhesion and conductivity.
41	Copper, fine	Reduction in coal gas ..	10	20	20	Two	Medium	Good	1.6	
42	Copper, fine	Reduction in coal gas ..	10	10	15	Two	Medium	Good	0.6	
43	Copper, fine	Reduction in coal gas ..	10	10	15	Two	Medium	Good	0.6	Reduced copper powder stored in stoppered bottle two days before mixing.
44	Copper, fine	Reduction in coal gas ..	10	10	15	One	Thin	Good	0.8	Satisfactory for adhesion and conductivity.
45	Copper, fine	Reduction in coal gas ..	10	10	15	One	Thin	Good	1.8	Reduced copper powder stored in stoppered bottle two days before mixing.

of the panel must be metallized. The electrically conducting metal powder spray in organic medium provides for this contingency. It is simpler than fixing a thin metal sheet, and is more economic than "metal spraying" (see next month's issue), which requires special equipment. At the same time it has its limitations, and must not be assumed to replace "metal spraying" in its many established applications.

(To be continued.)

PLASTICS IN BUILDING

"The Practical Use of Plastics in Building and Structural Work" was the subject matter of a discussion recently held by the Institute of the Plastics Industry, the Plastics Group of the Society of Chemical Industry, and the Institution of Structural Engineers. Mr. E. G. Couzens presided.

Mr. F. S. Snow, a consulting engineer, presented a series of questions put by members of the Institution of Structural Engineers in their desire for information about plastics.

Dr. A. Caress, in answering these questions, pointed out that the 1,300 varieties represented only about 24 chemical types, depending in this country upon the basic materials: Coal (with limestone for acetylene production), salt, and cellulose. Although the raw materials were plentiful, the making of plastics from them involved a network of chemical intermediates and complicated processes leading to relatively high prices and small production. Some people thought that plastics should be used only for decorative moulding and perhaps panelling and resin-bonded plywood. Others said that now was the opportunity to increase the production of plastics tenfold almost overnight. He took the middle view—optimism tempered by knowledge of the tremendous amount of work lying ahead before a fraction of the possibilities of plastics could be realized. He was optimistic because out of the two dozen chemical types of plastics, three-quarters had developed largely in the past 12 years. The immediate and important point was that plastics should be used only under those circumstances to which they were suited. At present there were severe limitations on their successful use in building, and very frequently there was no need to replace existing materials. If the plastics article was sound with advantages over other materials at a not excessively high cost, then specimens should be tried, and if successful brought into use in increasing numbers.

Mr. R. J. Schaffer (Building Research Station) said that the possible use of plastics as load-bearing materials in buildings in place of steel, wood, brick or concrete was a subject on which there has been misconception in the public mind. On the replacement of brick and concrete, it should be remembered that, although not numbered as plastics, clay could be regarded as a thermosetting plastic and Portland cement as a cold-setting plastic. Was it necessary to replace these materials? Considered as load-bearing members, plastics lacked the ductility needed in structural materials to smooth out stress concentrations and to give timely warning of overloading. The effect of this lack of ductility had been strikingly shown in experiments on the reinforcement of concrete with plastic rods. On loading, the stress was liable to be concentrated in one rod until it broke, throwing the whole load on another rod, which broke in its turn. Whilst, in general, plastics as such could not at present be considered as eminently suitable for structural work, the advent of synthetic glues opened up new fields for the structural use of plywood. There were building uses for which plastics had proved quite suitable; it was better that available supplies should be usefully employed for purposes to which they were really suited than wasted in attempts to put them to uses better served by other materials.

JUTE WASTE UTILIZATION

"Textile Weekly," which has frequently published articles dealing with the relationship of plastics to that industry, refers in a recent issue to the developments of the researches of the Indian Central Jute Committee. These have now resulted in preliminary plans for the chemical utilization of jute and jute waste products as a result of the work of Dr. B. C. Guha and Mr. Das, whereby mill jute waste is used with chemicals and a plasticizer to give a moulding powder.

Routine Working of Polyvinyl Chloride and Polyisobutylene

Based on an Account by Klant ("Kunststoffe," 1942/32/307)

Dealing with the Plant and Equipment Required for the Industrial Working of the Thermoplastics Vinedur and Oppanol

APPLICATIONS of polyvinyl chloride and polyisobutylene cover, broadly, three separate fields:—(1) tube for pipe installations; (2) polyvinyl-chloride plate, block, tube, and rod as material of construction for chemical plant and fittings; (3) foils as protective coatings for containers, apparatus and tubes.

Tube Working for Machine and Apparatus Construction

The equipping with the necessary machinery of the works to be considered here is to be viewed in the light of the first and second applications detailed above. The economical working of polyvinyl-chloride tube for piping installations, and of the same plastic in plate and block form for constructional purposes, requires the provision of machines and apparatus not necessary where operations consist merely in the covering of metal containers with thin protective films; this last activity entails mostly hand work.

The technique for working any given material of construction will be governed, primarily, by the properties of that material. Thus, in the case of polyvinyl chloride, which may be shaped either by hand- or machine-cutting operations, and may be equally worked up into the requisite form by plastic deformation processes, the machine shop concerned will, in a degree, reflect the many sided nature of the material. It should not be forgotten that the material can be welded and assembled by adhesives, as well as by standard methods of joining.

The low specific gravity of polyvinyl chloride (1.4) and the relatively low power required in cutting operations performed on it, or necessary for its plastic working, imply that the requisite plant need be far less heavy than that employed, say, for metal working. On the other hand, the arrangement of a machine shop must be such that bulky semi-manufactured forms can readily be manipulated. Tube lengths in polyvinyl chloride, for example, run up to 4 metres, whilst sheets may be as large as 1 m. by 2 m.

Machines and Machine Tools for Cutting

Polyvinyl chloride may readily be shaped by machining with all the commoner types of tool, but the operation becomes economical only when very high cutting speeds are employed. Figures somewhat in the order of those used for light metals and wood represent fair average values. High-speed plant, is, therefore, required.

For cutting various semi-manufactured forms to given lengths, breadths and thicknesses, bandsaws and circular saws should be provided, the teeth and set of which should not be coarse, otherwise the material is likely to splinter. Bandsaws should be 10-15 mm. wide, with gaps between the teeth of 3 mm. and a tooth length of 2 mm.

Tooth spacing of circular saw for polyvinyl chloride should be 6-7 mm. Circular saws should have tables adjustable for height and angle of cut. A minimum set of about 0.5 mm. is required both for bandsaws and circular saws in

order to attain free cutting conditions, otherwise smearing of the tool is likely to occur.

High-speed centre lathes should be provided, the number and size of the machines being fixed according to the output desired. For normal purposes, lathes with a swing of 300 mm. and with 1 metre between the centres are suitable.

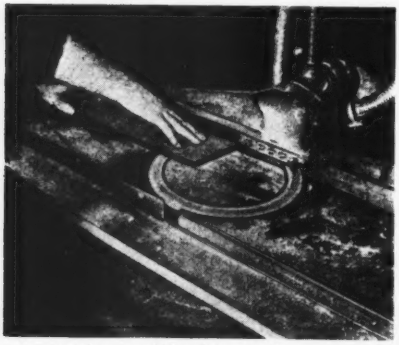


Fig. 1 (above).—Wheel for surface trueing of polyvinyl-chloride sheet. Fig. 2 (right).—Light electric saw for cutting discs, large packing rings, or irregular shapes from plastic sheet.

For mass production purposes semi-automatic, and for certain purposes, fully automatic lathes are recommended. Conditions of organization govern the decision as to whether these machines shall be installed in the plastic working shop or whether the operations shall be undertaken in the turning department of the works concerned.

Cutting tools for lathes should be tipped with the ordinary high-speed steels, and should be provided with a cutting angle equivalent to that used for light-metal machining.

The milling machine is a useful and economical tool for the shaping of plastics. In this connection cutting speed and tool form demand similar requisites as in the case of lathe tools.

In the case of so-called rotary files, or profiling tools (with shafts 6 mm. dia.), the common compressed-air-operated grinder or electrically powered grinder form useful driving media. Considerably higher production rates are possible with tools such as these than can be attained with the hand scraper, file or rasp. If such apparatus as we have described be mounted on a drilling post, it will perform very well as a vertical milling machine.

High-speed drilling machines are necessary for boring. A drilling machine with a radius of 300 mm. and capable of drilling holes up to 20 mm. in steel is generally sufficient for all ordinary purposes. Apart from the usual twist drills, core drills have proved very satisfactory for holes up to 70 mm. dia.

Whilst the shaping of polyvinyl-chloride plates on the planing machine is quite possible, it is important to observe that the type of plant used for metals is not satisfactory. First, because the cutting speed obtained is insufficient and, secondly, because the tool when

running back is liable to cause splintering.

For finishing and removing raw edges on mass-produced parts a sanding belt treated with coarse silicon carbide gives good results.

An edge-trimming device is absolutely essential. By means of simple attachments this equipment can be used for bevelling the edges of plates to prepare them for welding. If the finishing process calls for treatment of numbers of round components by grinding (the trimming

up, for instance, of plastic-covered rollers), centreless grinders, as used for metal, can be employed. The wheels used should be silicon carbide of medium grain and bond. In order to avoid any undesirable heating up of the work, dry grinding should be avoided, and wet grinding employing any of the usual emulsions is to be preferred.

Where irregular shapes have to be cut,

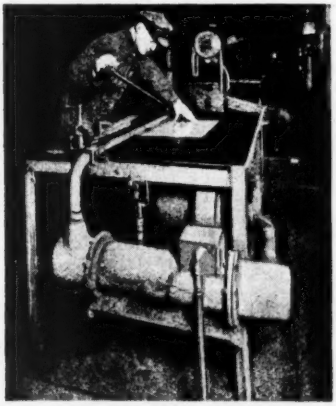


Fig. 3 (above).—Hot bending polyvinyl chloride sheet. The work table is equipped with apparatus for providing the necessary hot-air blast. Fig. 4 (right).—Producing large-diameter tube in polyvinyl chloride by winding sheet around a special former.

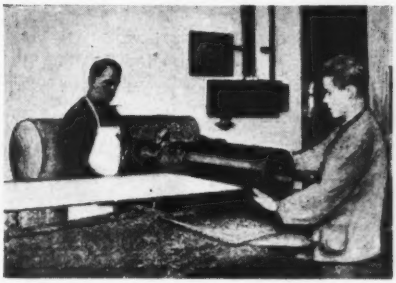
or where, for instance, polyvinyl chloride must be formed into washers or packing pieces for pipelines, small electric fret saws are extremely useful. So far as other tools are concerned, more especially files and scrapers, those used for metal can be employed with perfect satisfaction on polyvinyl chloride.

Apparatus for the welding of polyvinyl chloride has been described in a previous issue of " Plastics."*

Equipment for Plastic Working

The fact that, in the heated condition, polyvinyl chloride can be bent, drawn, pressed and blown, indicates in a measure, the equipment required for a workshop devoted to the plastic working of this material. Energy of deformation at the working temperature of 130 degrees C. is very low, suitable heating apparatus consisting either of an electric forced-air circulating furnace or of a steam-heated hot-air oven. The size of the oven is governed by the dimensions of the semi-manufactured component to be shaped.

In order to work up sheet and tube into various pressed forms, the use of a pneumatic press is recommended. This should be of such size as to exert a pressure of about 5 tons when supplied with air at 100 lb. per sq. in. It is essential, however, that the press be of a rapid working type in order that premature cooling of the plastic when placed on the die be avoided; the ordinary spindle press is not so satisfactory in this last regard. Platens of 750 mm. square will be found convenient for most purposes. If hardwood dies be employed, pressing will be found an economical proposition even for small outputs. If, of course, metal dies heated by steam, hot oil or



electricity be available, the oven-preheating operation of the sheet can be omitted.

In bending sheet polyvinyl chloride to special shapes and sections, it is necessary that the area to be bent should be brought up beforehand to correct temperature for plastic forming. In Fig. 3 such an operation is shown in progress, heating being by means of hot-air blast.

*"Plastics" 1943/7/53.

The blower and the electric heater are fitted under the bending table in this case. Compressed air from an airline may be employed in place of air from the blower if required. Alternatively, the plate may be clamped on formers with built-in electric resistance heaters, or, more simple still, an open flame can be used for bringing the former to the required temperature (blowlamp or

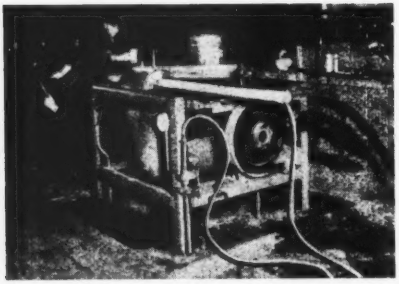


Fig. 5 (above).—Bending table for polyvinyl-chloride tube. Hot-air blast apparatus is mounted below the table. Fig. 6 (right).—Bench fully equipped for general manipulation of polyvinyl-chloride tube and sheet.

bunsen burner operating with luminous flame).

For forming up sheet to large diameter tubes for exhaust ducts and so on, the special apparatus shown in Fig. 4 is very useful. The sheet, previously preheated, is held under tension at one end, the other end being clamped into a slot in a wooden roller of the required diameter. It is rolled around this latter, quickly cooled and drawn off in the form of a cylinder.

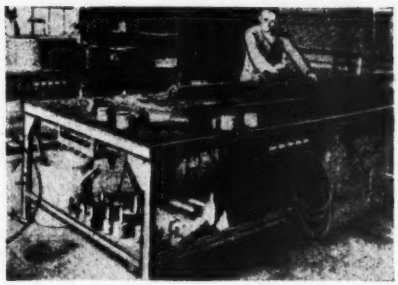
The bending table, shown in Fig. 5, is designed for the bending of tubes. A hot-air apparatus is mounted below the table as before. Hot air required for heating the zone to be bent emerges through an adjustable slot in the plate, the tube being covered on the outside by a shield. The tube may be filled with sand or a special rubber former may be employed. After bending, the tube is rapidly cooled in water.

Auxiliary Equipment and Apparatus

Apart from the equipment necessary for the machining and hot shaping of polyvinyl chloride and polyisobutylene in their various forms, output requirements will necessitate the provision of various auxiliary equipment, amongst the most important of which will be that for welding of sheet and tube.

For preparing sheet for welding shears will be necessary. For the testing of welded components, pressure apparatus and electrical conductivity measuring devices must be provided.

The working space allotted to operatives will depend upon the class of work undertaken, and particular attention is necessary where long lengths of tube or big areas of sheet must be manipulated. If possible, it is desirable that the bench incorporates apparatus for the production of hot-air blast and tube-bending fix-



tures. Points from which connections may be made to supplies of town's gas or hydrogen and electricity should be fixed, together with connections for a compressed air line.

Coating Shop

For those departments concerned with the protection of metal equipment by means of applied coatings of polyvinyl chloride or polyisobutylene, one or other of the available shot or sand-blasting equipments is essential. This should be contained in a closed, well ventilated, and, if possible, air-conditioned room, the size of which will depend on the

dimensions of the jobs to be handled. This practice is preferable to that of sand-blasting in the open, where not only is there a danger of moisture condensing on the freshly treated surface, but, at the same time, opportunity for re-oxidation of the clean metal; both of these possibilities may adversely affect subsequent adhesions of the foils.

Handling Devices

Shops handling heavy equipment to be coated with plastic foils must be provided with necessary conveyors and lifting tackle, the capacity of which will, of course, depend on the size of job and the output envisaged.

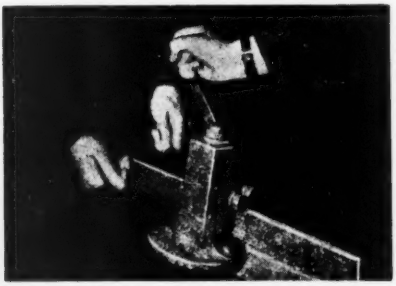


Fig. 7 (above).—Equipment for scarfing light-gauge polyisobutylene sheet. Fig. 8 (right).—Small end mill for finishing butt welds in polyvinyl-chloride cladding.

Power Supplies

Either town's gas and compressed air, or hydrogen, are required for heating iron surfaces to be coated with adhesive for the application of the foils. The electrically heated type of hot-air welding torch is recommended for softening the foil prior to application on wood or concrete. Compressed air will be required for grinding and finishing.

Plant and Auxiliary Equipment

As already noted, no machine tools will be required for the application of foil coatings; shears and a small saw for the cutting of washers are desirable, however. An ample supply of small hand-tools is necessary for manipulating the foils and for finishing off joins and welds. Wire brushes will be required for local touching up on sand-blasted surfaces and for removing unwanted adhesive.

For the application of adhesives, special brushes should be provided in order to avoid contamination of the adhesive film with bristles. Cheap brushes can prove very costly.

Polyvinyl-chloride film is best applied to the walls of containers by means of a hammer with a well-rounded "dolly."

Needless to say, the electrically heated hot-air welding torch finds a number of applications in this technique. For the lap jointing of polyisobutylene, an electrically heated soldering iron can be used. For this material also, a special hot-spraying device has been evolved for the application of the necessary bituminous adhesive, the spreading of which is assisted by means of spatulas.

Ventilation Requirements

The adhesives used for the application of these foils will entail considerable health hazards to operatives if adequate ventilation be not provided. Shops should thus be roomy and should give adequate headroom. When operating in closed spaces breathing apparatus supplied with fresh air from outside must be provided. Supplies of fresh air should also be introduced to the interior of closed vessels by means of flexible metal tubing.

World's Industry Employs Plastics

GENERAL ENGINEERING

Technical data on laminated plastics are given in a paper by R. W. Barber, Panelyte Division, St. Regis Paper Co., presented before the American Society of Mechanical Engineers ("Mechanical World," 1943/113/465). Physical values, such as bend strength, tensile strength, compression strength, shear strength, Izod impact, fatigue strength and water absorption, are detailed for paper-base, wood-base, fabric-base, glass-cloth base and special high-strength paper-base plastic laminates. Figures are given for various directions in relationship to lamination. The "Compreg" glass-cloth laminate is specially mentioned. The impact strength of this is given as five times that of the usual fabric laminates. **Tests to determine the bearing strength of commercially available high-impact moulded and laminated sheets and resin-bonded birch plywood,** give curves for load versus deformation as per cent. of bearing-pin diameter, and load versus permanent set as per cent. of bearing-pin diameter. The tests demonstrated the inferiority of plywoods in bearing strength as compared with the reinforced plastics. Heating, in most cases, improves the bearing strength of specimens, whilst soaking in water definitely decreases the strength as compared with specimens conditioned at room temperature and a relative humidity of 55 per cent. (ASME. Trans. vol. 65, 1943, p. 9.) **Surface finish of water-lubricated resin bearings is of greatest** importance for their durability. Reference to this fact is made by C. P. E. Howard in a discussion on a paper on surface finish by Schlesinger before the Institution of Mechanical Engineers. A thrust bearing loaded to 300 lb. per sq. in. was run against hardened-steel tilting pads. A number of changes was tried out, but a surface finish corresponding to a slip-gauge standard of accuracy (so that the surface would wring together) gave bearings which ran for many hundreds of hours at full load. The loadability of these bearings is now up to 1,600 lb. per sq. in. with water lubrication, with no sign of limit except the bursting of the test ring. **Italian Pat. 874,574 covers the production of solid or hollow parts** of cellulose derivates or other plastics, by centrifugal casting. **Influence of the chemical constitution of plastics on their mechanical properties,** in particular in the field of lower temperatures was investigated by K. H. Hauk ("Kunstoff Technik und Anwendung," vol. 12, 1942, p. 215). The following materials were investigated: cast phenol-formaldehyde resin (Dekorit 200a); polyvinyl-chloride (Igelit); polystyrene (Trolitul); cellulose triacetate with 0 to 40 per cent. plasticizer. Materials were tested in the range + 20 to − 70 degrees C.

AIRCRAFT

Curing of synthetic-resin wood adhesives by resistance heating is treated exhaustively by Egner in "Mitt. d. Fachausschusses für Holzfragen," No. 29, pp. 65-84 (Berlin, 1941). The use of Tego films containing embedded conducting wires designed for the passage of a low-tension current forms the principal

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item of study. In particular, massive blocks of unseasoned wood may, it is said, be built up by this technique. Reference is made to additional technical data in "Kunststoffe," 1938/28/208. **Aircraft wind shield** is made by embedding a sheet of specially prepared "Butacite" (polyvinyl-acetal resin) $\frac{1}{2}$ in. thick between two sheets of semi-tempered glass each $\frac{1}{8}$ in. thick. The plasticizer content of the resin core is adjusted to give maximum toughness at average temperatures attained during flight. The plastic sheet extends about 1 in. beyond the glass and is bolted to the metal framework. An abrasion-resistant plastic may also be substituted for the rear glass plate in the composite. The windscreen includes a front pane in tempered glass $\frac{1}{4}$ in. thick separated from the panel proper by a narrow air space through which hot air can be circulated. ("Automotive and Aviation Industries," 1943/88/50.) **Recent improvements in plywood manufacture** were reviewed by Perry of the Resinous Products and Chemical Co. at the Aircraft Production Session of the Institute of Aeronautics. ("Automotive and Aviation Industries," 1943/88/42.) Resistance heating and induction heating are being increasingly employed to cure synthetic-resin bonding and impregnation media. According to Perry, phenolic-resin adhesives in deep joints, such as occur in a laminated spar, can be cured only by induction heating. Scientifically designed scarf joints have now made it possible to splice plywood into sheets as large as can be conveniently handled, such joints having a strength of 80 per cent. or more of the parent material. Special attention is drawn to the use of paper laminates in aircraft construction. **Non-metallic materials in war and peace** are dealt with in "Mechanical Engineering" for March, 1943. R. J. Nevesar, Chief Engineer, Universal Moulded Products Co., Bristol, Va., contributes a paper on moulded plastic-bonded veneers of wood in aircraft construction, giving tensile and compression strength data for various materials. **Screw-in type anchor inserts,** consisting of a thin shell threaded inside and outside, have been designed for use in wood and metal fabrication, such as plastic plywood aeroplanes. Only one blind hole needs to be drilled in wood before installing the insert, and it taps its own thread. However, in plastics or soft metals the inserts are to be screwed in tapped holes; in plastics also moulded holes can be used. In order to prevent turning small nails are driven in slots ("Automotive and Aviation Industries," March, 1943). **More important advantages of plastic-bonded plywood** are discussed in a recent paper by G. B. Parsons, New York ("Transactions of ASME," January, 1943, vol. 65, p. 1). Some of the basic strength characteristics are presented. It is predicted that, in the near future, with glueing technique advancing rapidly, a thin metal covering glued to a plywood core will be used to great advantage in aeroplanes having high wing loadings. Such construction will combine the high axial strength of metal with the good buckling characteristics of thicker plywood construction.

CHEMICAL

Resistance of neoprene to various refrigerating agents is discussed by Lawrence in "Refrig. Eng.," 1941/112/404. Primarily devoted to a study of the use of this material in refrigerator construction, the account provides valuable data as to the resistance of neoprene to prolonged contact with a wide variety of organic and inorganic reagents. Sulphur dioxide has little effect; methylchloride swells many types of neoprene, but resistant mixes can be compounded. Ammonia, which can cause natural rubber to deteriorate, has little effect on neoprene. Of the fluorine and fluorine/chlorine organic agents, CF_4Cl_2, appears to have no swelling influence, even after about two

years' immersion, whereas $CFCl_3$ causes considerable swelling even after so short a period as two months. The cost of neoprene is stated to be 25 per cent. higher in U.S.A. than natural rubber. **Welded rotor for exhaust fan** handling acid-laden air is described by Dammer in "Masch. Bau./Betrieb." **Suitability of Buna rubber for high vacuum sealings,** investigated by R. Jaeckel and E. Kaumann ("Zeitschrift f. techn. Physik," vol. 23, 1942, p. 85). The gas leakage of various synthetic rubber-like materials was examined and compared with the corresponding properties of natural rubber. It was found that the suitability does not depend on the raw rubber quality but on the plasticizer and the fillers. Certain grades of Perbunan are in particular equivalent to natural rubber, in spite of a strong and characteristic smell. These are to be preferred for high vacuum sealings owing to their superior properties as regards ageing, temperature stability and oil resistance.

ELECTRICAL

Lacquered wire in telephone engineering forms the subject of a research report by Wolff and Pohler, reproduced in "Electr. Nachr.-Techn," 1941/18/156. The technological advantages of thin lacquer films of high dielectric capacity are compared with those of the silk or cotton insulators commonly used. Lacquers based on natural oils and gums, synthetic resins, and mixtures of these two groups are examined. Particular stress is laid on the influence of stoving temperature and times on the electrical properties of the insulating coating. Requirements (in Germany) of insulated wire are summarized, testing methods and equipment being described. It is interesting to note that lacquered aluminium wire has been sometimes preferred to anodized wire in Italy.

MISCELLANEOUS

Devices for regulating moulding temperature are discussed by Brandenburger in "Kunststoffe," 1942/32/247. The author distinguishes between coarse and fine thermostatically operated switches of the bi-metallic and mercury types, and defines the requirements, advantages and limitations of each. The need for accurate control of temperature and duration of heating is emphasized. **Future of plastics** is discussed from the technical and economic standpoints by A. Schmidle in a brief note in "Kunststoffe," 1942/32/252. The enthusiastic misuse of these materials by engineers is commented upon, together with the relationship between war-time consumptions dictated by necessity and the more stable but potentially constantly enlarging peace-time consumer demand. The relative spheres of plastics and metals are defined. **Metal economy in die designing** is discussed by Weprek in "Kunststoffe," 1942/32/83. The author shows that, in certain cases, a saving of up to 45 per cent. can be effected in the amount of alloy steels used in conventional dies, whilst an overall saving of 80 per cent. of steel, by weight, may be possible. These results are achieved by the use of built-up dies with inserts, in place of those cut exclusively from massive blocks of steel. The use of plates in place of machined frames is also advocated. Numerous practical examples are described and appropriate drawings given. **Course of fracture in Plexiglas** formed study described by Elle and Struth in "Z. techn. Phys.," 1940/21/393. Comparison was made with fracture mechanism in common glass, by means of optical-stress examination. Fracture was initiated by means of a bullet fired at an angle to the surface of the specimen. The elastic-wave spread was observed directly. In the case of Plexiglas, the circular wave

front seen in glass was absent. Velocity of spread of fractures varied in case of the plastic, although, for any given fracture, rate of progress did not alter. The influence of plasticizers is commented upon, and the query is raised as to whether, in the case of an unplasticized mass of, say, polyvinylacetate, the mechanism of fracture depends at all on the dimensions of the macro-molecules concerned. **Wood is the most important raw material of the future,** says N. C. Brown in "Mechanical Engineering," March, 1943. It is likely to be more important to civilization than either metals, minerals, oil, rubber or ceramic products. He stresses its relative cheapness. In the same issue the **principal characteristics of important textile fibres,** such as silk, cotton, rayon and polyarmide fibres are dealt with in detail. Karpow deals with the war rubber problem of U.S.A. **Tensile test bars with cupped hollow ends,** specially designed for investigation of plastics, were tested and described by Frischmuth ("Schweiz. Archiv. f. angew Wissenschaft und Technik," 1943/8/24). Test bars were made in ten different plastics—phenolic resin with woodflour filler, asbestos powder and fibre filler and textile filler; urea resin with asbestos fibre filler, cellulose fibre filler, and woodflour filler, melamine resin with cellulose filler and with woodflour filler. Specimens were moulded by five different concerns, and, for each material and moulder, 6-12 samples were tested, 408 being examined in all. It was found that strength variations lay between the usual limits and that average values of tensile strengths depend very much on moulding conditions. In spite of the improved form of the test bar, 50 per cent. of the specimens still broke outside the gauge length. **Applications and unusual physical properties of synthetic rubber,** for instance resiliency of rebound efficiency, cold resistance, resistance to heat and ageing are dealt with by Cole in ASME. Trans., vol. 65, 1943, p. 15. Data on tensile strength and oil resistance are included. The article gives a good survey on some of the commercial rubber-like materials on the market or in advanced stages of development at the present time. **Behaviour of common and high-density plywoods** is considered by Dietz and Grinsfelder in ASME. Trans., vol. 65, 1943, p. 187. Plywood and laminated wood bonded with phenol-formaldehyde resin and with cold-setting urea-formaldehyde resin are examined. M. Finlayson, Armstrong Cork Co., presented to the same association a paper on the **physical properties of high-density plywood produced from Tego-bonded birch veneer,** the grain direction of all plies being parallel. The properties of these materials are compared with those of metals. The strength properties are directly related to specific gravity. Stress-strain curves in tension indicate that this material not only has no normal yield point, but actually shows a decrease in elongation per unit load at high loads. The moduli of elasticity in tension and compression are greatly different. Behaviour in torsion, the effect on tensile strength of cross laying the veneers, the effect of immersion in water and the effect of various humidity conditions are discussed. I. P. Taylor deals in the same journal with the heating of wood by radio frequency power (loc. cit. p. 201) and C. G. Marra examines the factors responsible for raised grain on oak following sanding and staining (loc. cit. p. 177). **Telephone housing which demonstrates the flow of plastic in the mould** is described in "Machine Design," vol. 15, April, 1943, p. 113. The model was produced by the Bell Laboratories using a clear moulding compound with a few white filler granules. Under heat and pressure the charge becomes plastic as it flows into the die. Each pigmented particle leaves a streak indicating its course through the mould. The method acts as a check on design and moulding technique and enables causes of flaws, improperly filled cavities, etc., to be determined. Dial indicator is equipped with bezel and front cover moulded internally in a transparent plastic.

Plastics in Aircraft Construction

A Discussion of the Types, Form and Fabrication of those Plastics Suitable for Building Stressed and Unstressed Parts of Aircraft

By D. Warburton Brown, A.M.I.A.E.

DESPITE the common belief that plastics in aircraft construction is new, this is not strictly true, because these materials have been used for a number of years for small unstressed parts. It is quite true, however, that during the course of the present war plastics have been developed and that they are now used for a great diversity of parts in the modern aircraft. The main difference lies in the fact that now plastics are used for structural and lightly stressed parts, whereas formerly their use was confined to unstressed parts where some special characteristic, such, for example, as electrical insulation, was of primary importance.

Plastics as used to-day fall into three main categories, namely:—

(1) Thermoplastic materials.
(2) Thermosetting materials.
(3) Improved wood materials.

Strictly speaking, the improved wood materials do not form a separate group of plastics, as materials in the first two groups are used in their manufacture. The characteristics of improved wood, however, are worthy of special consideration, and will, therefore, be dealt with under a special heading.

Each of the above types of plastics has its own peculiar properties, and these properties, roughly, govern the applications for which each type is used. Thermoplastics are, in the main, used for their transparent properties, although in the present-day aircraft there are numerous applications of opaque thermoplastics for such items as heating ducts and ammunition boxes. The thermosetting group are confined to lightly stressed structural parts—for example, control pulleys, etc., and the improved wood materials are used for relatively large structural parts and assemblies. To-day there are many examples of aircraft in which the fuselage, wings, and tail units are all constructed from wood veneers bonded together under heat and pressure with plastic adhesives.

Just as each of these three main material groups has its own characteristics, so does each have its own limitations and drawbacks. It is proposed, therefore, to deal with each of these groups, as applied to the manufacture of aircraft, in more detail.

Thermoplastic Materials

The thermoplastic materials, which embrace such plastics as cellulose acetate, the acrylic resins, the styrene resins, and the vinyl resins, all soften with the application of heat, and harden again upon cooling.

At the present time the acrylics and cellulose acetate materials are by far the most important, and are used in large quantities by the industry. As has been previously mentioned, these materials, typical of which is " Perspex," are used largely on account of their extraordinary transparency, which makes them particularly suitable for gun-turret enclosures, observation domes, and bomb-aimers' windows. Apart from their exceptional optical properties they are extremely light, but against these points must be weighed their liability to surface scratches and the variation of strength with temperature changes.

Cellulose acetate, apart from the trans-

parent variety, is used to a considerable degree for non-stressed internal fittings. Apart from heating ducts and cartridge boxes, which have already been mentioned, other typical uses are for cartridge feed roller tracks, ammunition ducts, dinghy stowage boxes, and numerous other similar applications.

Thermoplastics should not on any account be used for parts subjected to stress unless a very careful analysis has been made of the effects of temperature and cold flow. In connection with temperature effects, the radiant heat from the sun should be given due consideration, as in tropical zones this can assume important proportions.

There are two methods in common use for manufacturing components from thermoplastic materials. The first of these methods, known as forming, consists of heating sheets of the material in ovens until they become soft and pliable, and then stretching it over wooden or metal formers of the desired shape and allowing the material to cool. Upon cooling it retains its new shape. Sometimes this process is carried out in presses, but, more usually, the plastic sheet is stretched over the former by hand.

The second method of manufacture is by straightforward moulding; that is, granulated material is placed in heated moulds and pressure applied by means of a suitable press. Thermoplastics can be moulded either by the compression or injection methods. In either case the mould must be allowed to cool before ejecting the component.

In connection with the forming of thermoplastic sheets it is necessary to keep in mind the maximum sizes in which the basic sheets are made. If large transparent assemblies are required, it may be necessary to design them from two or more pieces which are to be subsequently joined together.

When considering the moulding of thermoplastics it is necessary to examine the available equipment and the limitations imposed thereby. Most of the moulding of these materials is done by the injection process, and there are not many injection moulding machines which are capable of handling articles of more than 12 oz. weight. It is important, therefore, not to design moulded parts which will exceed this figure. A further point is that the time cycle for injection moulding is in the region of 30 seconds, and, therefore, this method of manufacture is only justified when large quantities of the component are to be made.

Compression moulding is still used to some degree, and here the size of the article to be moulded is limited by the

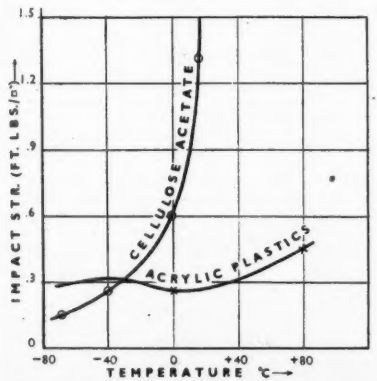

Fig. 1.—Variation of impact strength of acrylic and cellulose acetate plastics with temperature.

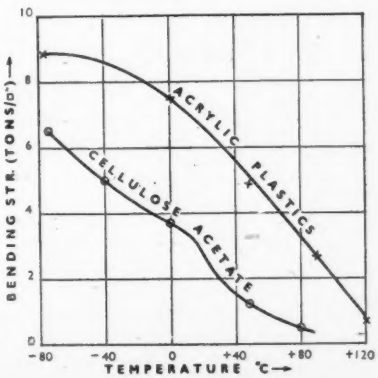

Fig. 2.—Variation of bending strength of acrylic and cellulose acetate plastics with temperature.

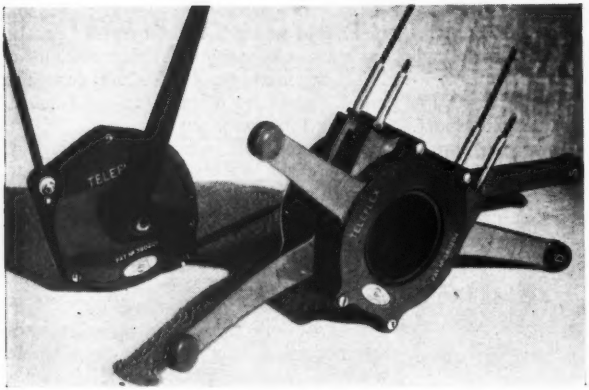

Fig. 3.—Aircraft controls in laminated phenolic material.
(Courtesy Bakelite Ltd. and J. Burns Ltd.)

over-all platen size on the available presses which can be determined by contacting the plastics manufacturer who will be called upon to do the actual moulding.

In general mouldings in thermoplastic materials should be designed to have a minimum wall thickness of .060 in., but heavier sections are always more desirable, especially if the component is liable to shock loads at sub-normal temperatures. The general importance of taking the operating temperature range when designing parts in acrylics and cellulose acetate can be seen from a study of Figs. 1 and 2.

When considering large formed parts such as pilots' enclosures, windscreens, etc., it is necessary to allow a tolerance of at least .125 in. on contours and those dimensions which cannot be jig controlled. Closer dimensional control can be obtained, but this usually entails special machining operations.

For moulding, a tolerance of .0025 in. per in. is considered satisfactory, but if there are several mould splits controlling the dimension a further .005 in. should be allowed for each joint. In addition, if the dimension crosses the mould flash line the addition of .010 in. is necessary.

Thermosetting Materials

The thermosetting materials form the second major group into which all plastics may be subdivided, and, as their name implies, they become hard infusible solids upon the application of heat. The heat cycle of these materials is irreversible, unlike that of the thermoplastics, and, once they have solidified under the action of heat, continued heating produces no further effect. Hardening of some of the thermosetting resins can be accomplished by the use of chemical hardeners, but in the main this method is confined to certain plastic adhesives.

For the purpose of aircraft construction the thermosetting materials used are almost wholly confined to the phenol-formaldehyde resins or phenolics, although small quantities of other materials are sometimes employed.

These materials are available in several forms, the chief of which are:—

(1) Laminated tube and sheet.
(2) Moulding powders.
(3) Laminated mouldings.

The laminated tube and sheet material is produced by impregnating sheets of paper or fabric with a resin solution, and finally pressing several layers of the impregnated material between heated circular moulds or plates. Under the action of the heat the resin first of all becomes viscous and finally polymerizes into a hard solid binding laminæ together. Aircraft components such as bushes, etc., can be produced from these materials by machining or punching.

Moulding powders are available in a

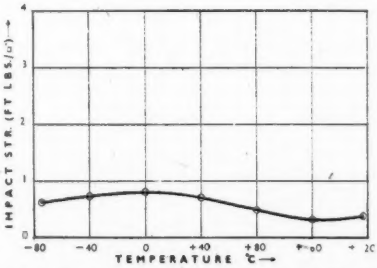

Fig. 4.—Variation of impact strength of general purpose phenolic moulded material with temperature.

wide diversity of forms, each with a filler chosen to give certain requisite properties. For aircraft components, however, the chief type of moulding powder will be those designated as the shock-resisting types. These consist of scraps of shredded fabric impregnated with phenolic resin, and although their impact strength is very low when compared with metals, they are sufficiently strong to withstand normal handling loads. Materials of this type are used for a number of small semi-stressed components such as brackets and containers.

When considering the use of semi-shock-resisting moulding powders it is not advisable to call for sections thinner than .150 in., since with smaller sections the shredded fabric filler may not penetrate into the mould, which will result in

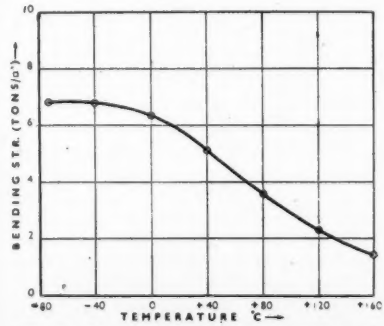

Fig. 5.—Variation in bending strength of general purpose phenolic moulded material with temperature.

pockets of pure resin occurring in the moulding, with a consequent variation in strength in different parts of the component. With general-purpose moulding materials appreciably thinner sections can be moulded satisfactorily, but the use of these materials is not advocated for aircraft components owing to their poor impact strength, which renders them liable to accidental damage. They are occasionally employed, however, for such items as control knobs and instrument cases.

It is again necessary to take into consideration the limitations imposed by existing equipment, which determine the maximum dimensions of the moulding.

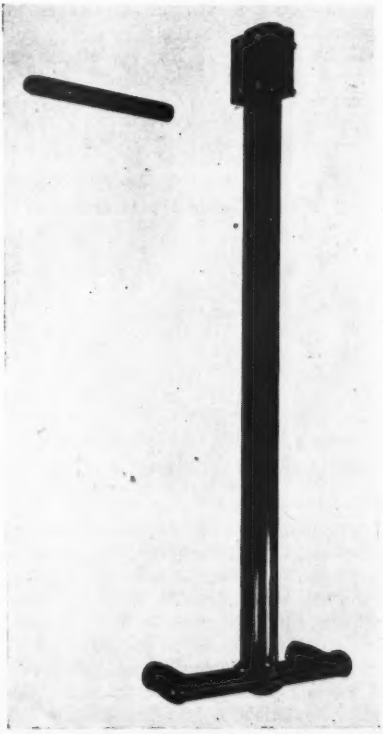

Fig. 6.—Aircraft aerial mast in laminated phenolic material.
(Courtesy: The Bushing Co.)

With regard to tolerances, these are substantially the same as for moulded thermoplastics.

Variations in temperature will also affect the physical properties of the thermosetting plastics, but not to the same degree as with those in the thermoplastic group. Fig. 4 shows the effect of temperature upon the impact strength of these materials, and Fig. 5 the effect upon bending strength characteristics.

There is a widespread belief outside the plastics industry that the use of these materials will result in an appreciable saving in weight, but it must be remembered that owing to the lower strength values of plastics it will in most cases be necessary to increase the general sections of the component, and sometimes the inclusion of additional strengthening webs will be necessary. Because of this the overall reduction in weight will not be as great as it first seems probable. Generally speaking, it is usually possible to effect a saving in weight in the order of 10 to 20 per cent.

Mould Laminated Material

It is also possible to produce mouldings from fully laminated, fabric base materials, but as the fabric can be stretched only to a limited extent without tearing, these mouldings are, generally speaking, confined to simple shapes, such as shallow pans and trays, although examples of more complicated forms have been produced with a fair degree of success. It will be realized that if the strength of the moulding is to remain uniform it is important that no tearing of the fabric should occur, because when this happens pockets of unreinforced resin are formed. The minimum thickness of laminated mouldings depends largely upon the type of fabric which is incorporated in the material. As a general rule, .060 in. should be regarded as the minimum when using the coarser grades of fabric, although with the fine-grade fabric materials it is permissible to use somewhat thinner sections.

The improved physical properties of the laminated mouldings make it possible to use them for semi-stressed components such as aerial masts and pilots' seats, but despite the fact that much experimental and development work has been carried out to determine their suitability for fully structural members, it is not considered that the laminated materials should be used in these cases owing to the present state of ignorance as to their behaviour.

Improved Wood Materials

It was explained earlier in this article that " improved " wood does not really constitute a separate type of plastic, but it differs so widely in its physical properties and in its applications that it is considered that it should be treated separately.

Basically improved wood consists of a number of thin wood veneers bonded together under heat and pressure by one of several types of plastic adhesives. The adhesives which can be used may be either of the thermoplastic or thermosetting type.

Wood veneer materials are generally supplied either in the form of flat sheets or moulded plywood. In plywood, the adjacent veneers have their grain crossed, but in the case of laminated wood the grain of adjacent veneers is parallel. In some cases the veneers are impregnated with resin before pressing, but it is more usual for the unimpregnated type to be used.

A serious drawback in the early development of the " improved " woods was that the casein and animal glues were subject to attack by fungi, but with the advent of the plastic adhesives this difficulty has been satisfactorily surmounted.

Although thermoplastic adhesives are used for bonding unimpregnated veneer material, it is more usual for the thermosetting type to be used. Generally this takes the form of a dry glue film. Improved wood materials made from impregnated veneers are now becoming available for the aircraft industry (particularly for propeller blanks), and in view of the enhanced physical properties of these materials it is to be expected that they will be used to a greater degree in

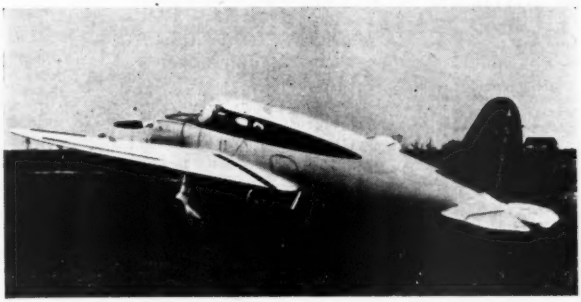

Fig. 7. — American training aircraft made from "improved wood."

the future when development and research have proceeded further.

The limitations upon the use of moulded unimpregnated materials are imposed by the method used and the equipment available. Moulded plywood components are made either by pressing in dies between heated press plates or by using one of the rubber bag or autoclave methods. In the former the size of component is obviously limited by the size of the presses available, due account being taken of the space occupied by the forming dies.

Possibilities of the Autoclave Process

When one of the autoclave methods is used, however, the limitation upon component size is governed by the overall dimensions of the autoclave in which the curing is carried out. Autoclaves are in operation having diameters ranging from 6 to 8 ft. in diameter by 20 ft. in length, although it is understood that larger equipment is under consideration. It will be realized, therefore, that, using this method of construction, components of considerable size can be made without difficulty. The pressures are low (40-100 lb./sq. in.), and the dies can be made from wood or sheet metal since they are not subjected to pressure stresses. In America a considerable amount of work has been done with large aircraft components made by this method. Fig. 7 shows an American training plane in which all the major units are made from "improved wood" materials.

Wood veneer materials can be made by either process in thicknesses from .030 in. upwards, and whereas it is permissible to use this thickness for internal parts where accidental damage by impact is unlikely, for general purposes it is recommended that an average thickness of .060 in. should be used. When used for exterior surfaces, such, for example, as wing surfaces, the material should be composed of five or more plies in order to prevent surface checking and fracture of the protecting coating. Three-ply construction produces a finished sheet which is stiffer in one direction, and this feature, under vibrating stresses, causes surface cracks.

When unimpregnated materials are used it is essential that the surface-protecting coat should be so applied that all the surface is covered. If this is not done, moisture will be absorbed into the plies under operating conditions and the material will deteriorate and warp.

Variation of Density of Improved Wood

The improved wood materials can be produced in various densities, the physical properties increasing with the higher densities. The high-density materials (density 1.4 approx.) can only be produced by the hot press method, and the size of component will therefore be limited by the press dimensions. Materials having a density of approximately 0.6 can be produced by either method, and, therefore, it is possible to form larger components in the lower-density improved woods.

INQUIRIES AND ANSWERS

(In Which is Included General Correspondence)

IMPORTANT NOTICE: If inquirers wish to receive replies by post, a stamped and addressed envelope must be included in their letter. Unless otherwise stipulated, it is understood that the submission of a problem to the Editor permits its publication in this journal.

Plastics for Motorcars

In connection with my recent article relating to the use of moulded wood veneer materials for motorcar body construction, it has been pointed out to me that the article gives the impression that only the very high-density materials with their attendant high physical properties are suitable for moulded plywood parts. As this is not the case, I should like to take this opportunity of correcting this impression.

The high-density material can be used locally for anchoring points, etc., but in general material having a density of approximately 0.9 can be used satisfactorily. The use of the lower density material effects substantial savings in production costs, as well as a reduction in weight. D. WARBURTON BROWN.

"Surco-American"

Can you give us any information on "Surco-American"? It appears to be a product of the Surprenant-Electrical Insulation Company, 82, Purchase Street, Boston, Mass., but we are rather interested to know the chemical origin of this material and as to whether it falls within the group of thermoplastics.

If you are aware of any literature we could obtain on this material we would be grateful for the information, or of any authority to whom we might inquire.

F., Y. AND T., LTD.

London, S.W.1.

[EDITOR'S NOTE: While we have not seen a sample of this material we have the following information: It seems certainly to be a thermoplastic material with rubber-like characteristics, since it has an elongation of over 400 per cent. It is moisture-proof with a dielectric strength of over 1,500 volts per mil, and can be used over a wide temperature range between 265 degrees F. down to −80 degrees.

It is non-inflammable and unaffected by oil, dilute acids and bases, so that on the whole we should imagine it to be either a polyvinyl chloride or a polyvinylidene chloride. It is used as insulating tubing, cable covers, gaskets and can readily be moulded.]

Plastic Trays

We are wanting to contact a firm willing to experiment in replacing wooden trays by plastic trays, to stand long periods of stoving at 130 degrees F. Can you advise us of any new or old firms who have recently embarked on this business? B. AND CO., LTD.

London.

[EDITOR'S NOTE: While ordinary trays moulded from phenolic and, we believe, urea resins, were quite well known before the war (they were made by Thomas de la Rue Ltd. and B.X. (Plastics) Ltd.), yet since the trays are to be used at 130 degrees F. for continued periods and for food products, information regarding possible contamination by odour of phenolics should be obtained from the manufacturers.

No doubt trays made from laminated material using urea glues as adhesives should also prove an interesting proposition.]

Jointless Flooring

On page 16 of "Plastics," January, 1938, there is an article about a material called "Comrok."

Is it possible for you to put us in touch with the suppliers of this material, as we are particularly interested in jointless floorings of all types? S., LTD.

Hants.

[EDITOR'S NOTE: The name is Komrok, and the material consists in a mixture of a siliceous compound and an organic binder of synthetic resin with or without a drying oil. It forms a doughy mass capable of being laid in the form of floorings. Applications should be made to Ernest Simmons and Co., 168, Regent Street, London.]

Sealing Porous Castings

The Use of Bakelite Resin Solutions for the Reclamation of "Leaky" Castings Usually Regarded as Wasters by Foundrymen

THE production of faulty castings in any metal is, in view of the technique and the raw materials, an unavoidable evil except by exceptional and lengthy precautions. This is no reflection on the art of casting which has progressed greatly in recent years. It is also true that unlike forging, castings cannot be worked to eliminate faults, so that any method which purports to utilize the faulty examples and make them usable is an important one.

Old and New Methods

The idea of filling up pores in faulty castings is by no means a new one. The treatment of wasters with sodium silicate, shellac solutions, boiled oil which deposit or form insoluble coating within or upon such faults has long been used. Nevertheless the results have been none too satisfactory in long service although some short-lived improvements have been achieved.

The new method to be discussed has been evolved by Bakelite, Ltd., the use of a special Bakelite sealing solution ensuring the production of parts to pass the most exacting inspection and tests. The results of its employment on a large scale have been confirmed by authority, and it now takes its place as an important aid in the war effort, so far as metal casting is concerned.

The treatment of castings to correct "leakers" has rightly been held in low repute because the materials hitherto offered as a remedy have not been capable of producing permanently sound and serviceable castings.

After treatment with a Bakelite sealing solution, a solid material—Bakelite resin—is left within the pores of the casting. This material is unaffected by water at any temperature, steam, and temperatures up to 400 degrees F. and even over. It is resistant to hot oil, alcohol and most chemical reagents.

The material is inexpensive (very little is required for each casting), no special apparatus is required and the process can be carried out by unskilled labour. The process is not suitable for the reclamation of cracked castings or those possessing gross defects such as blow holes; such castings must be plugged or definitely scrapped. It is intended for castings where the leakage is due to spongy metal, which is a much more difficult defect to correct. It is claimed that scrap has been reduced from 40 per cent. down to less than 1 per cent. Thus, every reclaimed casting is a direct saving of money, time and labour. The process is especially welcome to engineers because it generally happens that the failure of castings is not discovered until a considerable amount of valuable machining has been carried out. The saving of man-hours is very great.

Results of Tests

Tests have been carried out to determine the merits of Bakelite sealing solution in comparison with water-glass, shellac, boiled oil, etc. The water-glass-treated castings started to leak after having been subjected to boiling water for four days; those treated with shellac leaked after 12 days. At the end of 130 days the castings treated with Bakelite sealing solution were still in perfectly good condition. Some castings treated by the Bakelite process pass the paraffin test at very high pressure.

The sal-ammoniac process sometimes tried upon ferrous castings has rarely been found satisfactory, besides being a lengthy process.

Simple and Inexpensive Plant

The main object is to fill the casting with the Bakelite sealing solution and to exert adequate pressure upon it so that the fluid is forced through the walls of the casting. This can be accomplished in two ways. The apparatus in either case is very simple.

A. (1) A force pump (with gauge) to deliver the solution and maintain a pressure of 100 lb. to 600 lb. per sq. in. These pressures will depend upon the strength of the casting; lower and higher pressures have been employed. A hand pump is quite suitable. Generally speaking, the casting should be impregnated at a pressure about equal to the test pressure.

(2) The jig (as used in hydraulic testing) can be used to "contain" the casting, two ports being left—one for connection to the pump, the other to act as an overflow.

(3) Pressure tubing with convenient fittings for passing the solution from the pump to the casting.

(4) An oven wherein the castings may be baked after impregnation. The annealing ovens generally available in a foundry or engineering works will do admirably. The temperature required ranges from 80 degrees C. up to 135 degrees C., although these temperatures need not be strictly observed.

B. Another way of applying internal pressure is to fill the casting completely and then to apply air pressure to the one open port used for filling the casting.

Types of Solutions

Two materials are available—Varnish V.1845 and Enamel N.2106. Varnish V.1845 is a solution of a special resin in suitable solvents. After the casting is impregnated with this solution it is heated in an oven whereby the solvents are dispelled, leaving behind (within the pores) a solid resin, capable of being further converted (polymerized) by heat to a condition when it is no longer soluble, and is quite infusible at any temperature.

The Enamel—N.2106, is a similar solution of Bakelite resin, but contains, in addition, a fine siliceous powder. Both these solutions have proved satisfactory for porosity in castings and although V.1845 is suitable for all metals, especially bronze, brass and nickel silver, N.2106 is suggested for ferrous and aluminium castings, and in general where the pores are of a grosser nature. The same procedure is used for both fluids.

Before impregnation, the castings must be dry, i.e., if the hydraulic test has just been carried out, they must be heated to remove the moisture in the pores. But, in this impregnating process the hydraulic test becomes unnecessary because the Bakelite solution itself can be used as the test medium and is then in position for baking. Further (and this is especially important in the case of ferrous castings) a thin film of varnish or enamel on the interior of the casting will protect the metal from corrosion.

Instructions for Use

(1) The castings should be free from moisture, dirt and grease.

(2) The blanking-off jig is set up leaving one inlet (at the lowest part of the casting) and one outlet (at the uppermost part).

(3) A pressure pipe should be connected from the pump (a hand force pump is recommended) to the inlet.

(4) Pumping is started and continued until the Bakelite solution appears at the upper outlet.

(5) The upper outlet is closed and pumping is continued until a convenient pressure is shown on the gauge (100 lb. to 650 lb. is usual). The impregnation pressure should be approximately equal to the test pressure. This pressure is maintained for about 10 minutes in order that the solution may penetrate the metal. After this time (if the casting is a "leaker") fine beads of the brown solution will appear outside corresponding to the porous patches. If air at adequate pressure is available, it can be used with excellent results in place of the force pump.

RUBBER INTO PLASTICS

Cups for collecting Latex from rubber trees have, of course, been made of many materials—cocoanut shells, metal, glass, earthenware. The interest in this new Latex cup, which is a very simple moulding in Beetle produced for The United Africa Company, Ltd., lies in the strange reversal of circumstances which have called in synthetic plastics to help production of one of the oldest of natural plastics.

B·I·P

BRITISH INDUSTRIAL PLASTICS LTD. · ONE ARGYLL STREET · LONDON · W.1

BELL TELEPHONE LABORATORIES USE THIS

12-oz. H-P-M PLASTIC INJECTION MOULDING PRESS

TO OBTAIN ACTUAL PRODUCTION DATA FOR THEIR NEW THERMOPLASTIC TELEPHONE PARTS

Shortage of metal has demanded intensive development work on thermoplastics as substitute materials for telephone parts, including such complicated forms as the combined set housing. To carry on this experimental programme the more effectively, Bell Telephone Laboratories have recently installed an H-P-M injection moulding press.

Perhaps your products can be moulded. May we help you to plan your production?

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(6) The casting and pump are disconnected and the excess of solution is allowed to return to the storage vessel for re-use.

(7) The casting may be wiped (if desired) with cotton waste moistened with a solvent. In some cases it may be desirable to swill out the casting with this liquid.

The casting is now placed in a suitable oven, well ventilated, at ordinary atmospheric temperature. Heat is applied so that for the first hour the casting is brought to a temperature of about 85 degrees C. After the solvents are removed, the temperature is raised to about 110 degrees C. for an hour and finally raised to 135 degrees C. for a similar period. In the case of aluminium alloy, the time and conditions of "normalizing" could be used for curing the Bakelite resinoid, thus economizing time and labour.

These times and temperatures are in general practice, but as the size and nature of castings vary greatly, no exact rule applicable to all can be given here, but in case of doubt advice is available.

The casting should now be fit for service, but if the sponginess is severe it may be advisable, in some cases, to repeat the process; otherwise its effectiveness can be tested as usual.

THE FUTURE OF COAL

World Interest in Plastics and Fuel Production

IN a recent survey of the American coal industry and its future, Mr. Ickes, the Secretary of the Interior, made reference to the possible diminishing oil production throughout the world and to the advisability of utilizing coal as a raw material for producing liquid fuels and plastics. He is seeking authority to build a plant for coal hydrogenation and states that Germany is producing 5,000,000 metric tons per annum and I.C.I. in Great Britain some 180,000 tons per annum. In advocating such production in the U.S.A., he presumed that technical difficulties could be overcome "by the simple expedient of borrowing engineers from I.C.I."

"Another industry dependent to a large degree on coal is destined to reach a new stature," proceeds Mr. Ickes. "I refer to plastics. Possibly, claims that are too extravagant are made for the future of plastics. Nevertheless, they are replacing critical materials. Along with materials for plastics, coal hydrogenation will make available the tar bases which serve as raw materials in several organic processes.

"Hydrogenation will increase the production of benzole and toluene for explosives. The quantity of coal that goes into the ultimate output of plastics may continue to be a small percentage of the total mined. The cost of synthetic rubber or gasolene produced from coal may be greater than the cost of natural rubber or gasoline refined from petroleum. But in weighing the value of coal hydrogenation we must take into account the economic advantages which may result from producing in a single plant such a range of products as gasoline, oil, raw material for rubber, plastics, explosives, pharmaceutical chemicals, dyes, etc.

War-Time Trade Bulletin

The War-Time Trading Information Bureau, of 17, Henrietta Street, W.C.2, has performed an exceptionally important service to the Nation in general and to those factories employed in war work in publishing these valuable bulletins, which keep industrial managers in touch with current industrial and commercial affairs.

The present issue—a Ministry of Supply number—also contains excellent surveys of Home Market Changes in 1942, Governmental Rulings, Post-war Security, Industry—a National Policy, War Material Production, Aerodrome Construction, Concentration of Industry, Aircraft—Allied Industrial Developments, Use of Films in Industry, Communal Feeding, and Catering by Contract. The main feature in this issue is a Survey of the Ministry of Supply, which deals with the work of the Ministry, such as Purchase of Munitions and Supplies, control of raw materials, Salvage and the functioning of the Machine Tool Control.

PRODUCTION NEWS

Raw Materials, New Plant, Works Organization, Control Apparatus, Research, Personal and Trade Notes

AUTOMATIC TRIP AIR VALVES.—In connection with the use of compressed air-operated equipment at chemical works, explosive factories, mines and other establishments, one of the difficulties has been that when the pressure falls below a certain limit the machine, or similar equipment, stops operating. Then, as soon as the pressure returns, or builds up by leakage, operation starts up again when unattended, constituting in some cases a danger, quite apart from other obvious objections, such as increased wear and tear and loss of power.

Electrical operation does not possess this disadvantage because it has been a relatively easy matter to design efficient no-volt trip devices which close down the motor. Now, however, the problem has been solved by Hopkinsons Ltd., of Huddersfield, which has placed on the market a new automatic trip air valve, in two forms, a larger size for compressed air mains, and a smaller size for the air supply pipe of individual machines. These valves come into operation automatically as soon as the air pressure falls below that at which the machines can be run and shut off the air supply, completely and permanently, until resetting has been carried out by hand. Both valves are of the same general design, although differing in detail.

The working principles of the smaller valve, for example, may be described in actual practice, according to the following schedule. Pressure accumulates in a space above the piston by air leakage past the piston rings, and holds a small relay valve on its seat. When the air pressure falls below the usual working pressure, however, a spring opens the relay valve, thus releasing the air above the piston to atmosphere. Consequently, the piston, which is of larger area than the main valve to which it is attached by a short spindle, is forced up by any pressure remaining in the system, and the main valve is closed.

Although total loss of pressure will permit the main valve to drop to the open position again, the restoration of the air supply will lift the piston and accordingly shut the valve. The latter can only be re-set by hand and cannot remain set unless the pressure in the system is sufficient to operate the machine. To re-set, the knob at the top of the equipment is lifted, thus closing the relay valve.

Included also is a control device at the bottom for regulating the speed of the machine, and when this is once set it is not interfered with, the starting and stopping of the machine being carried out by a knob at the top which, on being lifted, closes the relay valve. Consequently, the pressure builds up above the piston and the main valve opens to the limit set by the hand wheel, the pressure also retaining the relay-operated valve to its seat. In order to stop the machine the knob is subjected to pressure by hand or given a slight blow, the result of which is to open the relay valve and close the main air supply valve.

This design fulfils the requirements of an automatic trip compressed air valve equal in convenience and efficiency of operation to the no-volt trip device of electric drive. It is robust in construction, has a powerful and definite closing force not dependent upon weights or springs, and which comes into operation almost immediately, ample clearance for the working parts (so as not to be rendered inoperative by dust and grit) and when once closed down cannot re-set itself.

ACID RESISTING METAL.—For high resistance to corrosion by acid and acid solutions, of outstanding interest is a special metal made by Meldrums, Ltd., of Timperley, near Manchester, which is not affected, for example, by sulphuric acid, nitric acid, acetic acid, chromic acid, oxalic acid, and many other acids, whether cold or at boiling point, and irrespective of the concentration. A special variety is also available which is resistant to hydrochloric acid.

Although, as with most acid resistant and also heat resistant metals and products, the full details are not available, it can be stated Meldrum metal is a high silicon iron, made by a special process. The firm has had an extensive experience in this field, dating from the past war (1914), and it has gradually perfected the metal until to-day satisfactory castings can be made up to 3 tons in weight.

The remarkable properties of silicon iron

are, of course, familiar knowledge, but one of the difficulties has been to produce castings of considerable weight and size. In general this special metal has an excellent heat conductivity and is extremely hard and durable, and much superior therefore to pottery and earthenware as regards withstanding changes of temperature and stresses. Further, it has the obvious advantage, as compared with any method of painting, coating, or enamelling, of being a uniform acid-resisting product right through, and therefore not affected, for example, by abrasive action, as well as changes of temperature already mentioned.

Further, the machined surfaces take a good finish by grinding, so that the metal is particularly suitable for such purposes as spindles on the ends of rollers in connection with equipment that contains acid.

It may be remembered that the firm also specializes on steam jet equipment for elevating, conveying, agitating, oxidizing, and other uses, and the metal is particularly valuable in this connection, since it can be used with any acid or acid solution, whether containing crystals or otherwise.

AGRICULTURE AND PLASTICS.—At an Institute of the Plastics Industry section meeting at Southampton on June 11, Dr. H. Barron spoke of the many contacts between the two industries and of the intense activities regarding them that are taking place in the U.S.A., U.S.S.R., Germany and other countries.

In America the application of agricultural products to plastics manufacture has been strongly supported by Henry Ford and has also been backed by the U.S. Bureau of Agriculture. It has recently received its greatest fillip from the synthetic rubber scheme.

Dr. Barron described the importance to the plastics industry of cellulose in the forms of cotton, woodpulp and straw, of protein matter, that is, soya bean and milk, of waste stalks, cobs and hulls for the production of furfural, of lignin which, both in its combined form in wood and in its extracted form, is used for producing building board, and, lastly, of alcohol, which is one of the most important of all raw materials.

PLASTICS IN INDIA.—Experimental researches conducted by the Mysore Iron and Steel Works have resulted in the operation of a plant for the manufacture of formaldehyde and phenol-formaldehyde moulding powder. In view of the very wide range of uses to which plastics made of synthetic resins can be utilized, the desirability of establishing the plastics industry in the State would appear to have received due attention at the hands of the Mysore Government. The pilot plant for the manufacture of furfural is nearing completion, and the manufacture, on a laboratory scale, of hexamethylene tetramine is being attempted. Coal research is also contemplated.

SYNTHETIC RUBBER PRODUCTION.—In the recent Dunlop report Sir George Beharrell has stated that during the current year and because of the increased supplies from America, we should see the temporary solution to the rubber problem. It has since been officially stated in America that production in the 40 plants there assures the United Nations of enough material for all military and essential civilian requirements. It is declared that during the full year about 250,000 tons will be produced, while next year production will rise to over 800,000 tons.

BAKELITE RESIN SALES.—Bakelite Ltd. announces that its Resin Sales Department has removed from Brackley to 18, Grosvenor Gardens, London, S.W.1.

NEW COMPANIES

BERGER PLASTICS DEVELOPMENT.—The wide interest of the Lewis Berger group of companies has been enlarged by the inclusion of Berger Plastics Development, Ltd. It will deal with new materials for plastic manufacture and will also undertake general development in this sphere. This concern, since it is one of the largest paint manufacturers in the world, has utilized synthetic resins in its products for many years. The directors of the new company are W. J. Darby, L. E. Wakeford, J. Macmanners and C. G. Fry.

PERSONAL

Mr. R. J. Ledwith, who has been closely associated with the development of Cerrux Marine Finishes, has been appointed chief chemist of Cellon, Ltd. **M. W. F. Wilson,** formerly chief chemist, has become manager of technical development.

Dr. W. E. Le B. Diamond, who has been assistant secretary of the Institution of Gas Engineers since 1937, has been appointed general manager of the British Plastics Federation.

Co-operation—
between User and Moulder

Dealing with some of the especial difficulties confronting the manufacturer of Precision Mouldings, and the various ways in which closer understanding between the User and Moulder may be established to ensure fullest and most satisfactory interpretation of User's requirements

By
W. M. HALLIDAY

IN the first portion of this article, published in the June issue, the writer endeavoured to indicate some of the chief ways in which much-needed co-operation, closer contact and understanding could be built up between the potential user and the manufacturer of precision mouldings.

Emphasis was laid upon the several important aspects arising in the development of mouldings possessing such characteristics, illustrating how the prospective user could assist towards this highly desirable and mutually beneficial co-operation.

In this present article it remains to examine in some detail the procedure adopted for handling the creation of the precision moulding throughout its various manufacturing stages, and at the same time to note particularly the main obligations towards co-operation and greater understanding which as a result devolve upon the moulder in his capacity of supplier of such articles.

We shall attempt to discover what measures will be required in order that he may be enabled to render the maximum contribution towards this end, and the simplest means of adapting such features into normal moulding manufacturing arrangements.

Checking the Client's Specification and Drawings

Assuming that the steps taken in the development of the moulding have progressed sufficiently for the user to have completed the specification along the lines indicated previously, stating the required features as well as able considering the limitations of his knowledge of the plastic moulding process and technique, the specification in this form will usually be inadequate for the moulder's purposes.

This submitted specification from the client, it will be noted, will have been conceived and expressed purely in terms of desirable properties or features which the finished moulding should possess.

For this reason, then, it will be almost imperative for the moulding manufacturer to consider the user's specification, drawings and other relevant documents from the angle with which he is specially concerned, i.e., the mouldability of the article and the technical or operational objections which might arise. As the moulding expert he is vitally concerned with such matters, and must approach any request for certain characteristics from this angle.

Needless to mention, it will be most unwise for the user to attempt any dictation of specific moulding features when advised by the moulder that their provision will conflict with sound moulding practice, or give rise to objections of other kinds.

As a preliminary, then, it will be the moulder's duty to subject all drawings, samples and specifications to very careful study and constructive criticism before he can justifiably submit to a client an adequate price or production quotation.

A very sound and useful plan adopted by the writer to facilitate such activities consists in the preparation of a draft questionnaire embracing all the necessary points upon which it has been agreed that a client's documents shall be investi-

PANILAX RESIN MOULDINGS

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A Moulded Resin without filler, which has outstanding electrical properties. It can, if necessary, be produced in small quantities without special tools, and is particularly suitable for intricate applications under severe conditions.

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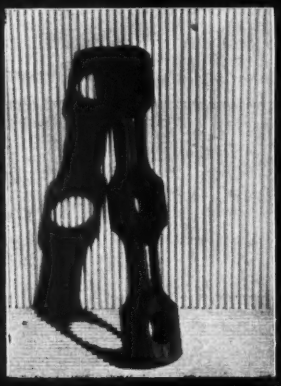

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gated or criticized. These may be printed or " roneod " forms, and adopted for use in all cases.

From experience it has been found that generally the following points require closest consideration, or, to put it another way, omission of due consideration of them is likely to lead to much trouble and objections. These points are best posed as questions as follow :—

(a) Is the drawing accurate in all its important details of measurements, configuration, dimensional tolerances, degree of finish, strength, wall thickness, coring, inserts, colour, etc.?

(b) Is the sample (if submitted) in accord with the submitted drawing, and if not note especially wherein departures arise, and bring to the user's notice?

(c) Are the physical, chemical, mechanical or electrical properties as specified on drawing or client's specification obtainable from moulding design, and if not inform user of reasons?

(d) Are degree of finish, appearance, smoothness, colours, etc., compatible with our normal moulding practice, mould construction methods, and mould operation?

(e) Are the user's suggested design of gauges, and his selection of gauging spots on finished moulding, the most suitable from the angle of moulder's knowledge and experience?

(f) Is it clearly stated who is responsible for furnishing gauges and all inspection equipment, and, if the user, have drawings of such appliances been submitted or are to be sent later?

(g) Quantities and date of delivery requested for sight of trial samples.

Upon the information elicited by such a questionnaire will be determined the moulder's ability to proceed with the important matters of powder selection, mould design, and analysis of its construction.

In considering the user's specification and kindred documents in the light of the above-mentioned questions, there may arise a number of points upon which the moulder will feel impelled to offer some criticism, advice or helpful suggestions for effecting modifications or adaptations of client's moulding design, so as to bring this latter more into line with the moulder's best practice, and so ensure a more satisfactory article.

It should be remembered that unless the moulder adopts such a course as this of making known quite unmistakably the various points of his disagreement, etc., with the client's projected design as expressed in the drawing, much trouble and dissatisfaction is bound to occur at later stages of the development.

Does Such Frankness Pay the Moulder?

In many quarters there seems to be considerable reluctance in being outspoken to this degree. It is held that many would-be clients will strongly object to such frankness and criticism on the part of the moulder during the initial stages of their contact, and as a result would take the business elsewhere.

This may be true, and the moulder by reason of his candour may find that he loses an order, but he would know that the user, in his short-sightedness, would undoubtedly encounter a heap of trouble and dissatisfaction later as predicted by the moulder. Hence, eventually in the client's estimations his credit would be enhanced because there would have been created a degree of confidence and reliance on the part of the user which would eventually materialize in tangible form by the placing of firm business later.

When satisfactory answers to the foregoing questions have been supplied by the moulder, perhaps after some consultation with the prospective purchaser, these are carefully filed away with all other particulars relating to job, and thus constitute a permanent and reliable record or guide for the whole job, and in the case of a normal type of moulding this record should obviate any further approaches to client respecting design, and features of the required moulding.

This, incidentally, is another strong reason why such critical consideration should be conducted right at the outset of negotiations and before the quotation is drawn up.

A close consideration of the foregoing seven questions will impart appreciation of the fact that the matters of mould design, its operation, rate of production, choice of most suitable powder material, determination and cost of subsequent spraying, finishing or machining operations, will all be affected by the information arising from such questions, hence their added importance to the moulder.

Selection of Suitable Moulding Powder

Having accomplished a satisfactory completion of the initial questionnaire the moulder will now be free to proceed apace with the other matters upon which decisions have to be reached before he is able to submit his quotation for supply of mouldings.

His next steps will then be to sketch in the conditions limiting or controlling powder selection and best results, and furthermore the main factors of mould design and moulding procedure generally.

His decisions respecting the most suitable grade of material powder to employ will naturally depend to a great extent upon the following:—

1. Where no strict limitations are stipulated regarding dimensional accuracy, interchangeability, shape of contours, the degree of warpage, flatness, or twist permissible, the moulder will be able to choose a low-flow powder which would greatly assist economical moulding, and at the same time render easier attainment of client's requirements.

2. In cases where the moulding is required to possess closely controlled dimensions and very accurate sizings, as a consequence of which the permissible warpage, distortion, or shrinkage must be maintained at a minimum, a powder of high-flow features must be employed.

3. Choice of high-flow powder will also be determined to some extent by the configuration of the component. If it should be one entailing intricate coring, or long thin walled sections, or having high-lustre finish to large areas of its surface, consideration of the ability of powder to withstand the higher moulding pressures and temperatures involved to secure those features must be closely watched.

4. The mechanical, electrical or physical qualities required in the finished article will also serve to guide the moulder or chemist in his task of selecting the most appropriate powder combination or grade.

5. Another important matter which is likely to affect the moulder's decisions is that of the stability and durability of the moulding, together with any special conditions to which it has to be exposed, such as weather, acid fumes, great heat, moist atmospheres, and so on. All such considerations should be taken cognizance of and allowance made by selection of powder most applicable.

6. Finally the moulder will also be compelled to take into consideration the cost of mouldings, mould, and powder supplies. Low-flow powders generally require a shorter curing time, therefore, other factors being equal, the moulding cycle is quicker and the production greater. Hence the cost per moulding will be somewhat less than if a high-flow powder has to be employed.

Selection of powder then must be such as will enable the best balancing out of all the other related factors in order that the most economical rate of production combined with the most satisfactory form of component is produced.

Having broadly decided upon the best type of powder to use, the next point arising is that of mould design.

Mould Design

Here again there will usually be a number of points influencing the design, and construction details of the necessary moulds, all of which must receive due consideration if the most satisfactory tool is to be produced.

The chief points arising in this connection of the initial laying down of mould design, etc., will be those relating to any possible modification to sizes, shape, location of cored portions, situation or type of inserts which can be effected in order to render the component

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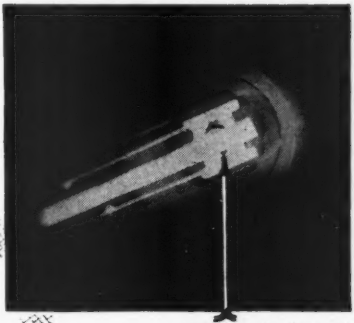
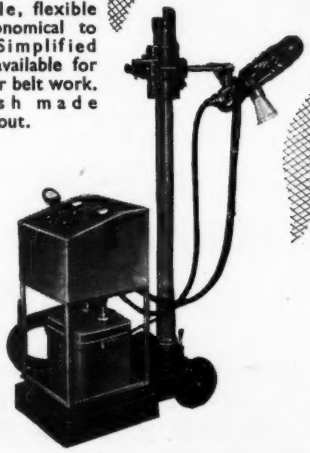


Radiograph of moulded assembly showing incorrect location of metal insert.



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more easily and more inexpensively to fit into ordinary moulding processes. The importance of this requires especial stressing, as its neglect may lead to expensive production both of the requisite mould and mouldings, thus making the difference between profitable and uneconomical manufacture.

For example, it may be found when the mould has been completed that the construction and design involve a much slower rate of production than originally envisaged. Sometimes this occurs and the moulder endeavours to secure a readjustment of quoted prices in order to cover him for this unforeseen excessive cost. This always results in dissatisfaction either for the moulder or user, or both, hence special care should be taken to ensure selection of the most suitable design.

The moulder will also be well advised to make a thorough study of all dimensional features required to be held within close limits to ensure that the mould design is such as will secure them throughout duration of the whole order and the completion of batch purchased. In the case of precision mouldings it is dangerously easy to fashion a mould which will produce satisfactory articles up to, say, 20,000 or 30,000, after which time variations arise due to wear of mould parts which leads to a departure from original accuracy and also a departure from the required dimensional accuracy of the mouldings.

So the moulder must keep his eye on the quantity order all the time lest he unwittingly furnishes a cheap mould which will not maintain its accuracy sufficiently long to complete the order.

Another question he must ask himself in designing the mould is, will the user's insistence upon certain size limits or other limiting factors be likely to create production difficulties resulting in a slower output, or a too cumbersome or costly gauging and inspection operation during the finishing stages.

If a projected mould design is such as to give rise to the foregoing the user should be advised.

Subsequent Operations on Moulded Article

Having settled broadly the type of mould design and method of moulding best suited to produce the required parts, before the moulder is able to submit his complete quotation he will still have to consider the question of all ensuing machining, painting and assembling operations which might be entailed.

It is advisable that the charges for such operations together with a statement of the precise work to be undertaken shall be itemized for the guidance of the client.

In cases where the moulding drawing calls for, say, tapped holes, or other features which the moulder may find it impracticable to provide, this also should be clearly stated in any quotation submitted by him.

Treatment of the moulding after leaving the mould, aiming at the elimination or reduction of warpage, bend, eccentricity, etc., should also be carefully considered in relation to mould design and method of operation of mould, and where special treatment is necessary this item should be indicated on his quotation.

Another important matter upon which both the moulder and user should be perfectly clear is that concerning the gauging or inspecting of the finished mouldings. As previously stated in the case of precision mouldings it is essential to institute an effective method of gauging those portions of component exhibiting precision features. Hence the moulder should first insist upon the receipt of gauge drawings, if not the actual tools, prior to commencing bulk production.

Many mouldings are required to have inserts in the form of tapped sleeves, bearing bushes, screws, studs, pins, dowels, rings, handles, dials, etc., these being as far as possible cast in position. In the quotation it should be clearly established as to who shall supply these, and the dimensional accuracy of same.

This is important, and where the client undertakes to furnish these the moulder will naturally require some guidance,

before he can fully develop his mould design, of the size tolerances which such parts will possess. If this is not afforded to him he may encounter considerable operating difficulties due to such insertion pieces failing to fit properly into the holding provisions formed in mould.

In this connection, by the way, the author can recall a number of instances where trouble has arisen on account of inserts supplied by an outside firm failing to adhere to requisite size and thus getting out of correct position in holding apparatus in mould, thereby ruining the moulding, with consequent high rate of rejects. Often in such cases it has been found advisable for the moulder to insist upon the inserts first being directed to user's premises in order that they be checked, or alternatively for the user to supply the moulder with proper gauges for his inspection of such parts.

Quantities

This is another important matter which should also be given careful consideration if possible at the initial stages of moulding development, and certainly before any proper quotation is drawn up. Apart from moulding costs being directly determined by the number of parts to be moulded, there are a number of indirect ways in which the batch quantity may exert an influence.

For example, mould design and construction will to some extent be conditioned by the number of components desired. In this respect the user should be advised in the quotation that the mould and tools designed for producing the parts bear a specific relationship to the quantity required. It should be clearly understood by the client that the stipulated quantity cannot be greatly exceeded generally without incurring some additional expense for reconditioning of mould and other tools.

In this connection most mould engineers will have a reliable idea as to the length of accurate operating service which may be expected from any given mould construction, and usually are also able to make sound estimates as to period of working or quantity of parts obtainable before normal wear and tear of mould results in departures from original accuracy standard.

The question of moulding quantity will also have a similar effect upon the tools, fixtures; jigs and inspecting appliances necessary for performing ensuing machining or finishing operations on parts. Usually the larger the number of moulded parts to be made the more care and labour can be expended upon provision of such tools, with their proportionately longer life in comparison to tools provided for the production of small or medium batches only. For these reasons then it will obviously be to the client's as well as the moulder's advantage to strive to make initial ordering as large as possible.

If such considerations are brought to the notice of the user it will be plain that any diminution of the quality of mouldings, or loss of accuracy on further orders after the initial order has been completed, cannot fairly be attributable to the moulder, and any modifications required of the moulds in order to secure a further supply must be mutually adjusted.

It might be urged that many of these considerations are not really the moulder's concern, or at any rate he is under no obligation to introduce them to the user's notice. If instances arise where dissatisfaction develops between the two interested parties then blame must be accepted by the user for his failure to specify such requirements which are the cause of disagreement.

Interpreting Customer's Desires

The answer to this line of argument is simple yet effective. It is this. The moulder should never lose sight of the fact that all his activities must be directed towards reasonable endeavours to supply sound and satisfactory mouldings faithfully exhibiting or interpreting the customer's desires. Such ends can only best be secured by the closest co-operation on the part of both interested parties.

Furthermore, it is also necessary to

remember that the user is rarely cognizant with design, mould and moulding production snags, limitations imposed by powder, and the hundred and one operational difficulties inherent in the process. Consequently he has no alternative but to rely upon the expert guidance which can only be afforded by the intelligent co-operation of the moulder.

Where this latter feature is lacking or meagre there is a risk that some important need of the client may be omitted or only partially met, with resultant disappointment to all concerned.

Need for Moulder's Co-operation with Powder Supplier

The moulder may retort that in some respects he is unable to furnish such reliable guiding information, or to give assurances to the client, say in respect of powder characteristics. This may be due to lack of sufficient technical, chemical or laboratory research facilities possessed by the moulder.

In such cases obviously the answer is that the user should not be allowed to suffer for such lack, and rather does it connote the need for close co-operation and contact between the moulder and his powder supplier, as the latter will certainly number at least one highly expert chemist among his staff who is competent to give sound advice to the moulder regarding features and use of powder.

In fact, there are several matters upon which he can usefully advise the moulder apart from such points as selection of appropriate grade to meet certain features, length of curing time, and working temperatures and pressure best suited to material.

The powder expert will be able to guide the moulder upon the degree of flexibility permissible or to be expected from any powder supplied. This is important because it enables the moulder the better to assess his ability to maintain precision features upon mouldings over substantial batches, or again, he can more easily decide what degree of variations are likely to arise in respect of any particular moulding characteristic.

The value of such guidance will be readily appreciated when related to the moulder's desire to obtain uniformity or exact duplicity of certain features throughout production.

The powder supplier will also be able to make very helpful suggestions for handling bulk supplies of powder purchased by the moulder to meet a large order. If certain precautions are not observed by the latter in his storage of such material difficulties and variations may arise in the case of some of the precision qualities of mouldings.

Storage of Powders

Most powders for example are produced by the powder manufacturer to a specified water-content. This varies, of course, according to different grades and types of materials. In most cases, however, there is a tendency for absorption of moisture which in satisfactory storage conditions may be so slight or slow as to produce little harmful effect, but in the case of large stocks stored in humid or very damp conditions a deleterious water content point may be reached which will produce puzzling difficulties during the moulding stages.

To avoid such difficulties large stocks should be stored on the moulder's premises in sealable kegs or metal containers, in a dry location, and means should be provided whereby the kegs can be tightly resealed after a supply has been drawn off for production purposes.

Powders actually being employed in the moulding shops should be stored in such a manner as will ensure their stable temperature in a reasonably dry atmosphere, otherwise harm may be wrought and wastage arise.

Enough has been indicated to illustrate the lines of approach and variety of questions which it is desirable the moulder shall consider before he submits his quotation to the user, the acceptance of which constitutes a commitment of both parties with regard to specified price and production terms.

(To be continued.)

Resinoids and Other Plastics as Film Formers

By B. J. BRAJNIKOFF,
Consulting Electrical Engineer

XIX (Contd.).—Electrolytic Aspects of High Polymeric Systems

The Mechanism of Conductivity of Electrolyte Systems

The progress in understanding of the mechanism of conductivity of the electrolytes was gradual. After the electrochemical researches of Faraday, the development of this problem may be divided into three stages. The first stage is characterized by the establishment of the basic dependence of the electroconductivity of solutions upon the concentration and the nature of the solutes, the second—by the correlation of these data with the general chemical theories, and, finally, the third stage—by the creation of the mathematical apparatus offering the possibility of the quantitative interpretation of the properties of electrolytes.

The classical exponents of the theory of the solutions—Mendeleeff, Arrhenius, Kablukoff, Werner—have intimately associated the process of formation of solution with the interaction of its two components: the solute and the solvent. The formation of electroconducting solutions and the peculiarity of this phenomenon (for example, the water solution of hydrochloride conducts electric current, but solution of the latter in hydrogen cyanide is non-conducting) still more emphasize this interaction. Kablukoff[269] already in 1892 has pointed out that the micelle of the solvent, interacting with the molecules of the electrolyte, aids dissociation, wherein the ions form with it the hydrates, and Werner depicted the process of hydration from the angle of his co-ordination theory.

A further evolution of the theory of the solutions resulted in a voluminous fund of information accumulated by the various schools of thought: that of Walden, Plotnikoff, Franklin, Kraus, and others. Despite, however, this great amount of recorded data, its integration into a single coherent theory has as yet proved infeasible, since the experimental facts and partial hypotheses are, unfortunately, still inadequate for the generalization of the quantitative methods.

For these reasons, it is important to present a critical résumé of the recent developments with the view to ascertaining how far the physico-chemical theories of forces acting between the ions correctly describe and explain the dispersion phenomena in an electrolyte and the practical conclusions which may be drawn therefrom for the utilization in technology.

The problem of the interaction between the solvent and electrolyte or in the case of tertiary systems (i.e., when a substance AB in a solvent C is non-conducting, but in the presence of a third component, S —the solvator, forms the electroconductive solution) of the electrolyte and solvator by various investigators is approached and solved in a different way. Some workers regard the solvent as a dielectric medium separating the ions and determine the force of interaction between them by Coulomb's law, the others still introduce into the field of the ions the known orientation of the molecules of solvent, and, finally, the third consider that the interaction of ion with the solvent is of purely chemical nature, that is the product of the interaction—solvate or more exactly, complex, is determined according to the laws of stoichiometry.

Thus, in the opinion of Walden, apart

from the physical (electrostatic) factors, there are involved some other factors of the chemical character, by virtue of their dependence upon (i) the chemical nature of cations and the ions of solute and (ii) on the chemical nature of a group of solvents. Plotnikoff[270] and his students explain the specific behaviour of a series of the examined electro-conducting systems, chiefly in the solvents with a low dielectric coefficient (viz., bromine, benzole, toluol, etc.) by the formation of complexes, solvates, high polymers. However, Plotnikoff devotes little attention to the questions concerning the nature of the forces which govern the formation of the products of interaction of solute with the solvent. In his treatise on the "Studies of the Electrochemistry of Non-aqueous Solutions," Professor Plotnikoff,[271] as far back as 1908, pointed out that the chemical interpretation of the electro-conductivity cannot be recognized as satisfactory. Professor Usanovitch[272] and his school in Russia, in their extensive and fruitful researches on ether solutions, arrived at a general conclusion that, fundamentally, in the binary systems, whose one component is an ether, the electro-conductivity results only in those cases when ether enters into a chemical combination of a certain type with the second component; this interesting aspect, which is clearly of great practical importance to the electro-deposition of synthetic resins and other plastics from lyophobe colloidal systems and kindred processes, will be treated in more detail in a later part of this section.

Verification by Experiments

A very valuable criterion and guiding principles for the verification of the physical and mathematical hypotheses relating to the ionic interaction are furnished by the deductions derived from a number of specially designed experiments initiated by Arnold and Williams[273] since 1928 onwards.

Thus, with the object of verifying the dispersion theory of Debye-Falkenhagen, the above investigators have succeeded in constructing an ingenious device of the type of the resonance comparator, affording the possibility of performing observations of the electro-conductivity and dielectric coefficient of dilute solutions of electrolytes at high frequencies with exceptional precision.

The forces acting between the ions exert an influence on both the reversible and irreversible processes taking place in the electrolytes. Thus the limiting law of the variation of the ordinary molar electro-conductivity, λ, dependent on the molar concentration, C, is expressible by $\lambda = \lambda_0 - \alpha \sqrt{C}$, where the term $\alpha \sqrt{C}$ takes into account the influence of forces acting between the ions, as postulated by Debye-Hückel-Onsager.[274] These forces condition the absence of the chaotic distribution of the ions in solution, for each ion is found surrounded by the ionic atmosphere, and due to this every ion exerts an influence upon the motion of another ion.

There are two different effects, which should be taken into consideration, namely: first, the effect conditioned by the direct action of the electric forces between the ions, and usually designated as the electric force of relaxation; and secondly, the hydrodynamic effect known as the electrophoretic force.

In a high-frequency field the electric force of relaxation decreases, and thus, in accordance with the Debye-Falkenhagen theory, there should occur the increase of electro-conductivity, provided that the frequency employed for the measurement determination is sufficiently high. The theory also requires that the increase of dielectric coefficient (or dielectric "constant" or permittivity) of the solution, compared to the solvent, should, under these conditions, diminish, tending to zero at an infinitely high frequency.

When through electrolyte is passed a continuous or low-frequency current, the state of asymmetry in the distribution of charges of the ionic atmosphere is being created in the direction of the current, and the ionic mobility is being reduced.

This asymmetry is being formed during a finite interval of time, and, in its turn, the disturbed symmetry is unable to be restored immediately after the action of the field vanishes, for this requires a certain finite segment of time, the so-called period of relaxation. If the field frequency increases to such a degree that the interval necessary for one oscillation becomes comparable to the time of relaxation, the asymmetry of atmosphere is not realizable. As the frequency rises the asymmetry decreases, with the result that the diminution of the ionic mobility occurs at a smaller rate. Theoretically the effect obtainable for the range of frequencies from 10^6 to 10^8 cycles per second is already of such an order that it can be detected and measured.

The following considerations of the qualitative character show why there takes place the variation of the dielectric coefficient in electrolyte solutions under the application of a high-frequency field.

Since the formation of the ionic atmosphere needs a definite time interval, it is observed that at high frequencies there occurs a noticeable displacement of the phase between the direction of the periodically varying electric impulse in relation to the ion and the ionic velocity itself, the effect of this superimposed high-frequency field being the emergence of a complex current.

Thus, besides the current component, which is in phase with the applied field and determines the conductivity, there is also still the displacement current. Experimentally, the latter is revealed by the change of the increase of dielectric coefficient of the system. Since this phase displacement is the function of applied frequency, it follows that not only the electro-conductivity but the increment of the dielectric coefficient as well will alter depending on the frequency. To make this point clearer, let us suppose that the positive ion during the time interval equal to zero is being displaced for an infinitesimal distance from its position in the centre of the ionic atmosphere.

In consequence of the relaxation period, ionic atmosphere in this event cannot immediately follow after the ion and continues to remain around the former seat of the positive ion. The displaced ion and atmosphere are connected by a quasi-elastic force into ionic couple, and the system (the displaced ion-atmosphere) thus formed, in so far as it possesses the properties of the electrical dipole, affects the dielectric coefficient of solution.

Until relatively recently there existed a rather widely accepted opinion that in the dilute solutions of electrolytes the dielectric coefficient of the system decreases with the growth of ionic concentration. The diminution of dielectric coefficient was explained by the saturation of the molecules of a liquid by the powerful electric fields by the dissolved ions.

The improvements in the experimental technique achieved of late are so substantial that the results obtained therefrom are far more accurate and trustworthy than heretofore. It has been found that under the conditions as stated above there occurs the increase of the dielectric coefficient, which may be attributed, mainly, to the formation of the ionic couples, due to the action of the electric forces between the ions. Hence it follows that the effects evoked by the electric saturation should be appreciably smaller than has been estimated by the exponents of the aforesaid view.

The data derived by Arnold and Williams[273] from their researches have proved to be in good quantitative agreement with the postulates of Debye-Falkenhagen and testify to the fact that the role of the above-mentioned effect of the electric saturation is very slight.

Thus, in the purely physical theory of the attraction between the ions Arnold and Williams find a satisfactory interpretation and description of dispersion of an ideal electrolyte.

In the dilute solutions the diminution of dielectric coefficient, conditioned by the saturation of the molecules of a liquid, as a result of the action of intense electric fields of the dissolved ions, is extremely small. The observed increase of the

dielectric coefficient of the system may be attributed to the ionic distribution as couples.

The Measurement of Dielectric Coefficient and Dipole Moment

Among the problems of fundamental importance relating to the molecular structure is that concerning the distribution of charges in the molecule. Modern quantum mechanics, which have succeeded in furnishing the statistical solution of an average distribution of charges in the atom, also provide, in the case of the molecules, the principles for calculating the distribution of respective charges. However, the difficulties connected with these computations permits them to be carried out only within a narrow range of special cases. Nevertheless, by approaching the problem experimentally it is possible to surmount these difficulties and to arrive at the distribution of charges in the molecule by determining the so-called " dipole moment," i.e., the distance of the centres of gravity of the positive and the negative charges, multiplied by the values of the electric charges carried by them.

In determining the dipole moment by experiment the basic role belongs to the measurement of dielectric coefficient (dielectric " constant " or permitivity), and the numerical value connected with it, in accordance with the Clausius-Mosotti theory, of the molecular polarization:—

$$P = \frac{\epsilon - 1}{\epsilon + 2} \cdot \frac{M}{d} \quad .. \quad .. \quad (1),$$

where ϵ is the dielectric coefficient, M molecular weight, d the density of a given substance, while the value of the molecular polarization, P, should be independent of the temperature and pressure.

Debye,[276] on the basis of deviations observed experimentally in a number of materials from their behaviour conformal to the formula (1), drew the conclusion about the existence of the permanent electric dipoles of given substances, and elaborated the theory which correctly represents the dependence of the molecular polarization on the temperature.

According to Debye, the value of molecular polarization, P, may be expressed in the form of two terms, the first independent of the temperature and conditioned only by the intro-molecular displacements which may be denoted, say, as P_e (evoked by electronic displacements); the second term, symbolizing the value that depends on the temperature, is conditioned by the force of the external field causing the orientation of dipoles, and may be called the polarization of the " orientation," P_o.

Now, by substituting these two terms in the equation (1), the latter is transformed into

$$P = P_e + P_o \quad .. \quad .. \quad (2).$$

The expressions derivable from the theory for the separate terms of (2) are:—

$$\frac{\epsilon - 1}{\epsilon + 2} \cdot \frac{M}{d} = \frac{n^2 - 1}{n^2 + 2} \cdot \frac{M}{d} + \frac{4}{3} \pi N \frac{\mu^2}{kT} \quad (3),$$

where n is the index of refraction, N the Loschmidt number, μ a dipole moment, k the Boltzmann constant, T the absolute temperature.

Whence from (3) is obtained

$$\mu = 0.0127.10^{-18} \sqrt{(P - P_e)\,T} \quad .. \quad (4).$$

Passing now to the experimental estimation of the quantities involved in (4), we see that of the values entering into (3) and (4), under usual conditions, the following may be considered as known:—n, the refractive index; M, molecular weight; d, the density of a substance under the examination; the least of all known is the value of ϵ the dielectric coefficient.

Besides the fundamental significance of the dipole moment—for the understanding of the molecular structure—the studies of Debye give interpretation of the physical role played by the molecular polarization itself. It is precisely Debye who draws the comparison between the latter process and the molecular volume. This circumstance indicates the way towards the exploration of the complex systems, regarding them as mixtures of a series of the components.

Thus, by this means, the investigator is apparently enabled to approach the solu-

tion of the problem relating to the " combined water " in colloidal systems,[277] carbons, powders, and the like.

The method, further, affords the possibility of conducting accurate analysis of the component parts of dielectrics,[278] a feature of vital importance to the film formation technique and applications.

Solvation and Complex Formation

With regard to the purely chemical approach to the electrolytes, note should be made, however, that this chemical aspect of the interaction suffers a duality which, so far, was not avoided by any of the modern electrolytic theories. Thus Walden divides electrolytes into (i) the normal, i.e., such which by themselves, in the state of fusion as well as in solution, possess electro-conductivity, and (ii) the potential, pseudo- or solvo-electrolytes, which in the fused condition are not electro-conductive, but, due to chemical and physical action, in the appropriate solvents may become electrolytes (solvoionization). From the discussion that follows it will be clear that the first group comprises the substances having " typically heteropolar structure," strong electrolytes.

Naturally, there arises the question, what role is played here by the interaction with the solvent, other than that in the case of the solvo-electrolytes? An attempt for classification, such as, for example, that which was suggested by Walden, by dividing the solvents into the levelling and differentiating, although neat in itself and useful in serving as a guide for the systematizing of the experimental data, still does not escape the duality in the interpretation of the electrolytic systems.

To obviate this duality, a somewhat different endeavour has been made by Finkelstein and his associates.[279] Although in complete agreement with the Walden definition of both groups of the electrolytes, these workers are, however, not inclined to draw a hard and fast line of demarcation between them.

The whole essence of the matter lies in the mutual influence of both ions on one another, in the deformation action of the cation upon the anion, as a result of which the bond is so strong that a pure liquid substance possesses the electro-conductivity of a certain order. However, in the opinion of Finkelstein and his collaborators,[280] the compounds, which under definite conditions become electrolytes, represent a mixture of the two types of the molecules, more precisely, a series of types: (a) those with a strongly deformed bond, and (b) the heteropolar or dissociated molecules. This view is not new; it has already been expounded some time ago by Wasastjerna,[281] then by Scheibe,[282] and others.

In contradistinction to the classical conceptions, Finkelstein and his colleagues consider that, since for one reason or another there came into being molecules capable for dissociation, or, as some authors define them, the molecules with the intermolecular ionization,[283] then the dissociation of such molecules proceeds to completion, in conformity with the electrostatic theory of electrolytes as postulated by Debye-Hückl-Onsager.

Affinity Between Solute and Solvent

The understanding of interaction with the solvent is, doubtless, much facilitated by the rich and valuable data derived from experiments with solvents of low dielectric coefficient, where the action of the ionic fields is highly pronounced, and the effects of solvation, association, etc., are manifest with particular clarity.

In the treatment of this problem, Finkelstein, like a number of other workers, made a reference in several works to the chemical affinity between the solute and the solvent, or the third solvating agent.[284] However, in the light of modern views on the interaction between the dipoles and the ions, the concept of this affinity, like that of the chemical or physical interaction, can already be postulated on a firmer ground.

As has often been pointed out by several investigators, the basic fact deter-

mining solvation, apart from the charge and magnitude of the ion itself, is the polarity of the solvating molecule. The notions of Bernal and Fowler[285] on the structure of the liquids and the influence of the ions upon the variation of this structure, and their calculations of the co-ordination spheres filled in a greater or lesser degree by the solvated molecules of water, still more emphasize the role of the dipole and structural properties of the molecules of the solvating agent.

The observations of Debye and Sack[286] are perfectly correct that the quantitative treatment of the association of the dipole molecules is a particularly difficult problem on account of its intermediate character between the purely chemical and physical nature. Still more complex is the picture of the interaction between the ion and dipoles. An effort to examine such an interaction has been made by Gorunoff and Samoilovitch,[287] in application to the influence of the ions on the association of the dipole molecules of water. These authors regard the action of the ions as the alteration of the statistical distribution, in consequence of which to the minimum condition of the free energy of the system corresponds the decrease of the association of water.

In the light of these results and all the above-cited facts, Finkelstein and co-workers arrive at the conclusion that the process of solvation and the complex formation cannot be described by any one physical or chemical theory. When the dipole enters the field of the ion, then, depending upon a number of conditions, in particular on that of the polarizing force of the ion (i.e., the charge and the radius), the magnitude of the moment of the permanent dipole, the polarizability of the solvate molecules, as well as upon the influence of the oppositely charged ion, we will have a more or less intimate bond between the ion and the molecule, starting from the orientation of the dipoles in the field of ions with a greater or lesser reduction of their kinetic freedom, i.e., the activity or effective concentration, which reveal themselves, in the above-mentioned cases, through osmotic properties of the solution, right up to the loss of the independent existence of the dipoles and the formation of a chemical compound.

In the case of solvates and complexes of non-polar molecules, the polarizing force of the ion might be so great that a complex may include such strongly non-polar molecules as those of bromine.

As an example of this may serve the platinum ion P^{+++++} in the solvents PBr_5 and PCl_5 in bromine. The combination of the five bromine molecules with PCl_5 has been found by Plotnikoff[228] and Jacobson, as was already stated before. In the latter case, during the electrolysis the chlorine is released at the silver anode, which indicates the dissociation according to the scheme:

$$[P.5Br_2]^{+++++} + 5Cl^{-}.$$

The Nature of Electro-conductivity of Non-aqueous Solutions

The principal shortcoming of all theories of electrolytes is that they are applicable only to the diluted solutions. Already Mendeleeff had pointed out that concentrated solutions should be of no lesser interest for the chemist than the diluted ones, and that the transition from the latter to the former is continuous and unavoidable. Meantime, neither the classical theory nor that of Debye-Hückel cover the concentrated solutions.

Another great drawback is the following circumstance: the Debye-Hückel theory is the theory of strong electrolytes, the classical theory until the present day still has certain significance in the field of the weak electrolytes, whereas the very division of electrolytes into the strong and feeble is devoid of a rational basis, and the suggestion of the two different mechanisms of electro-conductivity is hardly justifiable.

And lastly, an extremely weak point of all theories is the ignoring of the chemical interactions that take place in the solutions, while actually, in a vast majority of cases, the electro-conductivity of the solutions depends on the formation of definite chemical compounds between the " solute " and the solvent, as has been

amply demonstrated by researches of various workers, the most notable of which are those of Usanovitch and his associates,[289] carried out at the Siberian Physico-Technical Institute. These workers, realizing the defects of the existing hypotheses on the dependence of conductivity of the solutions upon the chemical interplay between the component parts, which were merely the qualitative explanations of the experimental data, were the first to make an attempt for the development of a rational quantitative theory embracing the whole multitude and diversity of the experimental facts, extending to all electrolytes and all concentrations. On the basis of the hypothesis that in binary systems (the combinations between the components act as electrolytes) the function of electrolytes belongs to combinations between its components, the formation of which is subject to the law of mass action, and that electro-conductivity of the solution is proportional to the concentration of the electrolyte, these investigators evolved an equation of the dependence of the electro-conductivity on the concentration for any degree.[290]

The Shortcomings of Existing Theories

The theory of Arrhenius, which has been built on the studies of the electro-conductivity of aqueous solutions, regarded the conducting solution as a combination of the two unequal components—the solute and the solvent (water). The existence of conducting and non-conducting solutions is easily explained (at first glance) by the circumstance that all dissolved substances fall into two classes: (i) electrolytes, i.e., the bodies capable of being decomposed into the oppositely charged parts—the ions—and which are realizing this ability during the process of solution, and (ii) non-electrolytes, that is, the substances in which, by virtue of their chemical constitution and structure, this property is absent.

In the first works of Arrhenius the variation of the electro-conductivity with the concentration was thought as connected with the formation of hydrates in solutions, but subsequently the notion of the chemical interaction between the solute (electrolyte) and the solvent (water) has been abandoned, merely assigning to the water the role of the physical medium, in which occurs the dissociation of the electrolyte into the ions. On the eve of the current century the prevalent view was that the electrolytes dissociate into the ions preferably in the water solution, to which has been ascribed the exceptional ability to promote dissociation of dissolved electrolytes (the ideas of Ostwald, Nernst).

For the reasons already stated, Finkelstein and his co-workers are of the opinion that the formation of an electro-conductive system in the event of both Walden types of the electrolytes is, in the qualitative sense, perfectly identical, the essential difference being only in the quantitative aspect, due to which the first type (i.e., the normal) are totally dissociated in the fused state, whilst the dissociation of the second type (that is, the potential or solvo-electrolytes) proceeds merely to a negligible degree. In this way the above authors have utilized the hypothesis of the two forms in order to avoid the duality of the complete dissociation for one group of electrolytes and the partial dissociation for the other type of the systems. In analysing the interaction between the solvent or solvator and the dissolved electrolyte, these investigators unified into a single scheme all the cases from the formation of the stable complexes up to solvation through the orientation of the dipoles of a solvate substance in the ionic field; these workers have also drawn attention to an important part played in a number of instances by the deformation polarization, which thus furnishes the explanation of the combining of such strongly non-polar molecules as bromine, benzene, etc.

However, even long before the advent of the theory of Arrhenius, there were known the facts relating to the electro-conductivity of non-aqueous solutions; soon after the introduction of the conception of Arrhenius, the number of these

facts began to grow rapidly owing to a great flood of the electro-chemical researches. The water ceased to be in the eyes of the workers as a sole solvent evoking the electrolytic dissociation of the dissolved substances, although the view still persisted that it possessed an extraordinary "dissociative power" as before. Having regard to the notion of the solvent, as a neutral medium, laid as a basis of the whole theory, it was necessary to explain those exceptional properties, which were attributed to water; the natural analogy has led to the result that almost simultaneously and independently from one another, Nernst and Thomson have found the interpretation of the "dissociative force" of water in its very high dielectric coefficient and have generalized this deduction with respect to all solvents: "dissociative power" is greater, the higher its dielectric coefficient.

The Nernst-Thomson rule logically follows from the consistent application of the electrostatic concepts to the solutions of electrolytes; however, a serious objection may be made against the introduction in this case of dielectric coefficient into the Coulomb's law: in applying this law to the sphere of macroscopic phenomena, we regard the medium as a continuum, since the individual discrete constituents of this medium belong to microcosm; a totally different picture is presented by the solutions of electrolytes, for here the molecular dimensions of the solvent are of the same order as the sizes of the ions, for which reason it is already impossible to regard the medium in this event as a continuum. Apart from these general considerations, there are a great many experimental facts, which strongly militate against the Nernst-Thomson rule, and, consequently, against the electrostatic view on the nature of electro-conductive solutions. Without entering into a detailed account of separate works, which is beyond the scope of this discussion, mention should be made of the remarkable researches of Plotnikoff,[271] who has established the electro-conductivity of the solutions in solvents with the low dielectric coefficients; according to the Nernst-Thomson rule, such solvents should possess a very small "dissociative power" and, consequently, the solutions of electrolytes in these solvents would not be expected to be the conductors of the electric current, or should conduct very poorly. In a large number of examples Plotnikoff was able to demonstrate that, with the appropriate selection of the component parts, it is feasible to find for any solvent a substance which forms with this solvent a conducting solution. The results of these investigations enabled Plotnikoff already in 1908 to affirm that the "parallelism between the dielectric coefficient and the electroconductivity at the present time may be considered as refuted."

A large number of exceptions from the Nernst-Thomson rule is also observed in the case of solutions having a high dielectric coefficient. Of special interest are the experimental researches of Fredenhagen[290] relating to the sphere of solutions in solvents with high dielectric coefficients. Fredenhagen's works devoted to the studying of the solutions of the most diverse substances in hydrofluoride acid have proved that the behaviour of the electrolytes in HF ($\epsilon = 84$) is entirely different from the performance which is observed in water solutions. Some of the typical strong electrolytes of the aqueous electro-chemistry (for instance, hydrogen halides) do not dissociate into the ions in the solution process in hydrogenfluoride acid; others (most/salts) enter into the reaction of a double decomposition and, consequently, cannot be dissolved as such in HF; the third (acids), although they form conducting solutions with HF, display a distinctly different scheme of dissociation, as compared with the solutions of the same bodies in water. Thus, for example, the nitric acid gives the complex cation H_2NO_3 + and the anion F^-; in all cases, generally, the role of the anion is played exclusively by the fluorine-ion. Besides this, a major quan-

tity of the organic substances form the conducting solutions in HF, i.e., is converted, as it were, from the typical non-electrolytes of the aqueous electrochemistry into "electrolytes"; such are the alcohols, carbohydrates, nitro-compounds, etc.

All these facts furnish an excellent proof of the inconsistency of the electrostatic viewpoint, ignoring the chemical nature of the components partaking in the solution.

Notwithstanding the works of Plotnikoff, Fredenhagen and other investigators, who oppose electrostatic theories, and who seem to have amply demonstrated the lack of correspondence between the Nernst-Thomson rule and the experimental facts, the opposite standpoint is still accorded up to now an almost universal recognition. A great role in the establishment of the prevailing views has been played by the researches extending over many years by the eminent worker Walden, whose results on numerous occasions gave the confirmation of the Nernst-Thomson rule.

The dispute concerning the applicability of the Nernst-Thomson rule, going on already for over three decades, is the reflection of the collision between two fundamental points of view on the nature of the electro-conductivity of the solutions and liquids, which may be designated as the electrostatic and the chemical concepts. Since the Nernst-Thomson rule logically follows from the first of these points of view (the application of the Coulomb's law to the solutions of the electrolytes), the inconsistency of this rule testifies to the fact that the notion of the conducting solution as a homogeneous mixture of the two unequal components—the solute (electrolyte) and the solvent (dielectric medium), and also the application of the electrostatic schemes to the solution should be rejected. It should be emphasized, however, that the chemical theories of the electro-conductivity have never met with a wide recognition. Even Plotnikoff, who stressed the role of the complex formation in the solution of the electrolytes, not only does not defend the chemical concept of conductivity, but objects against its acceptance.

(To be continued)

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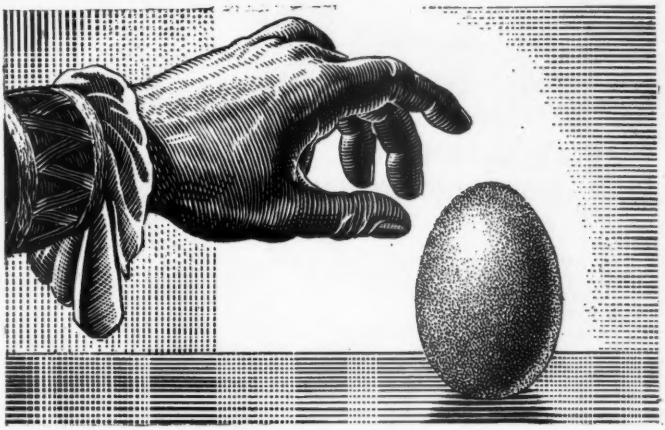

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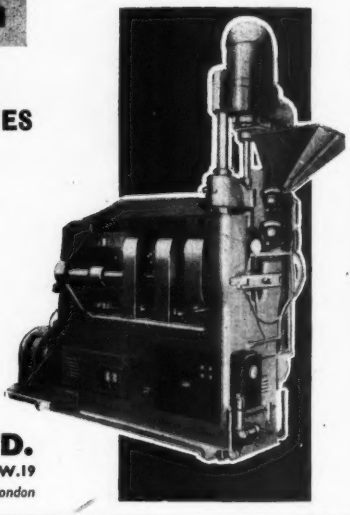

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